

Research Paper

J. Astron. Space Sci. 36(2), 75-86 (2019) https://doi.org/10.5140/JASS.2019.36.2.75



New Light Curves and Orbital Period Investigations of the Interacting Binary System UV Piscium

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UV Psc is a typical RS CVn type system undergoing dynamic chromosphere activity. We performed photometric observations of the system in 2015 and secured new *BVR* light curves showing well-defined photometric waves. In this paper, we analyzed the light curves using Wilson-Devinney binary code and investigated the orbital period of the system. The combination of our light curve synthesis with the spectroscopic solution developed by previous investigators yielded the absolute parameters as: $M_1 = 1.104 \pm 0.042 \text{ M}_{\odot}$, $R_1 = 1.165 \pm 0.025 \text{ R}_{\odot}$, and $L_1 = 1.361 \pm 0.041 \text{ L}_{\odot}$ for the primary star, and $M_2 = 0.809 \pm 0.082 \text{ M}_{\odot}$, $R_2 = 0.858 \pm 0.018 \text{ R}_{\odot}$, and $L_2 = 0.339 \pm 0.010 \text{ L}_{\odot}$ for the secondary star. The eclipse timing diagram for accurate CCD and photoelectric timings showed that the orbital period may vary either in a downward parabolic manner or a quasi-sinusoidal pattern. If the latter is adopted as a probable pattern for the period change, a more plausible account for the cyclic variation may be the light time effect caused by a circumbinary object rather than an Applegate-mechanism occurring via variable surface magnetic field strengths.

Keywords: eclipsing variables, photometry, RS CVn type

1. INTRODUCTION

RS CVn type system is a detached binary showing very dynamic chromosphere activity (Hall 1976). These systems are composed of rapidly rotating late-type or giant stars (Kim et al. 2014). The light curves of RS CVn type systems show a distortion wave caused by stellar activity, particularly at outside eclipse phases. The wave changes continuously according to variations in cool spots. Moreover, angular momentum loss (AML) can occur via magnetized stellar winds induced by the chromospheric activity of the system, which finally decreases the orbital period. Therefore, long-term photometric observations of RS CVn type systems are important to more clearly understand these phenomena.

UV Psc, discovered by Huth (1959), is a representative RS

CVn type system. The distortion wave was clearly observed in the previous light curves of this system (Oliver 1974; Sadik 1979; Vivekananda Rao & Sarma 1981, 1983a; Zeilik et al. 1982; Antonopoulou 1983, 1987; Han & Kim 1988). This phenomenon was interpreted as being caused by the existence of cool spots (Budding & Zeilik 1987; Han et al. 1996; Radhika & Vivekananda Rao 2001; Vivekananda Rao & Radhika 2002; Kjurkchieva et al. 2005). The radial velocity (RV) curves for both components were determined by Popper (1991, 1997), and Kjurkchieva et al. (2005) despite the fact that it is not easy to measure the spectral lines of the less massive component due to its fast rotation. The observed RV curves indicated that the mass ratio of this system falls within the range of 0.7 to 0.8.

Many investigations of variations in the orbital period have been performed to understand the dynamic properties

Received 13 MAY 2019 Revised 28 MAY 2019 Accepted 30 MAY 2019 [†]Corresponding Author

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of the UV Psc system, but the orbital period variation of this system remains controversial. Sadik (1979) and Kjurkchieva et al. (2005) suggested a decreasing orbital period, while Hall & Kreiner (1980) and Milano et al. (1986) proposed an increasing orbital period. Shengbang et al. (1999) suggested that the orbital period oscillates with a period of approximately 61 years and a semi-amplitude of 0.21×10^{-5} days.

In this study, we investigated the physical properties of UV Psc using new multiband photometric light curves obtained during the observing seasons in 2015. An overview of our observations is provided in Section 2. Sections 3 and 4 contain the investigations of the light curves and orbital period variation, respectively. Finally, we summarize the results presented in Section 5.

2. NEW OBSERVATIONS

New photometric observations of UV Psc were performed at Jincheon station of the Chungbuk National University Observatory (CBNUOJ) over 12 nights from October to November 2015 using the 60 cm reflector installed by the Korea Astronomy and Space Science Institute and operated by CBNUOJ. The telescope was equipped with an electronically cooled SBIG STX16803 4K CCD camera at a f/2.92 prime focus. A field of view of $72' \times 72'$, and an image scale is 1.05 arcsec pixel⁻¹. Standard *BVR* filters were used during the observations with different exposures from 30 to 90 s according to the weather conditions for each observation. Further details regarding the telescope and instrument systems can be found in Han at al. (2015). The brightness values of the field stars were measured using aperture photometry and all images were corrected with bias, dark, and flat-field image. All reduction processes were performed using the IRAF package. TYC 26-70-1 and TYC 26-1046-1 in the UV Psc field were chosen as the comparison (C) and check (K) stars, respectively; further information is listed in Table 1. During the entire observation period, observational errors were calculated using the standard deviations of the differential BVR magnitudes between the K and C stars, were 0.^m013, 0.^m014, and 0.^m015, respectively. A total of 2913 observations were obtained (973 in B, 972 in V, and 968 in R), and a representative sample data set is listed

Table 1. Star information from the Tycho-2 Catalog (Høg et al. 2000)

Name	RA. (J2000)	DEC. (J2000)	B [mag]	V[mag]
UV Psc	$01^h 16^m 55^s .119$	+06° 48' 42".11	9.73 (3)	9.01 (2)
TYC 26-70-1	01 16 18.491	+063437.25	11.06(8)	9.70 (3)
TYC 26-1046-1	101741.429	+063532.43	11.88 (13)	11.50(14)

in Table 2.

3. LIGHT CURVE SYNTHESIS

3.1 New Light Curves of UV Psc

Fig. 1 shows the *V* light curves calculated by the ephemeris (Kreiner 2004):

$$C = \text{HJD } 2452500.0411(\pm 0.0007) + 0.^{d}8610468(\pm 0.0000003) E,$$
(1)

where the black dot and red cross represent the data measured before and after HJD2457315, respectively. The light curve shows light variation of approximately 0.^m05 at the primary eclipse where the more massive and hotter primary component is transited by the less massive and cooler secondary component. This value is larger than that of the observational error. In contrast, the brightness at the secondary eclipse remained unchanged. These facts may imply that the spot effect of the less massive component predominates in this light curve.

3.2 Binary Modeling and Absolute Dimensions

In this light curve investigation, we used the BVR data acquired before HJD2457315. To model the BVR light curves of UV Psc, Wilson-Devinney binary code (Wilson & Devinney 1971; WD) mode 2 for the detached binary systems was used. The temperature of the more massive star (T_1) and mass ratio $(q = M_2/M_1)$ were fixed as 5780 K and 0.733, as determined by Popper (1997) and Kjurkchieva et al. (2005), respectively. Considering that RS CVn type system consists of two late-type main-sequence stars with convective envelopes, the gravity darkening coefficients and bolometric albedos for both components were assumed to be $g_1 = g_2 = 0.32$ and $A_1 = A_2 = 0.5$, respectively (Lucy 1967; Rucinski 1969). The limb-darkening coefficients obtained using the logarithmic law were adopted from the table developed by van Hamme (1993). The projected rotation velocities of the primary and secondary components measured by Kjurkchieva et al. (2005) were $v_1 \sin i = 66$ and $v_2 \sin i = 54$ km/s, respectively, while the synchronized rotation velocities calculated by the absolute parameters in Kjurkchieva et al. (2005) were $v_{\rm 1,syn}$ = 67.0 \pm 2.3 km/s and $v_{2,\text{svn}}$ = 49.9 ± 5.3 km/s, respectively. Because the projected rotation velocities are in excellent agreement with the synchronized velocities within the errors, we assumed the rotation parameters to be $F_1 = F_2 = 1$. In addition, the

В	BV			R	
HJD	Δm	HJD	Δm	HJD	Δm
2457301.0266	-1.328	2457301.0255	-0.664	2457301.0259	-0.336
2457301.0287	-1.325	2457301.0275	-0.651	2457301.0279	-0.342
2457301.0348	-1.345	2457301.0295	-0.656	2457301.0299	-0.341
2457301.0388	-1.332	2457301.0315	-0.667	2457301.0320	-0.342
2457301.0408	-1.333	2457301.0336	-0.663	2457301.0340	-0.342
2457301.0428	-1.336	2457301.0356	-0.660	2457301.0360	-0.334
2457301.0467	-1.333	2457301.0376	-0.659	2457301.0380	-0.346
2457301.0487	-1.325	2457301.0396	-0.660	2457301.0400	-0.339
2457301.0506	-1.341	2457301.0416	-0.656	2457301.0420	-0.341
2457301.0526	-1.322	2457301.0436	-0.658	2457301.0440	-0.345
2457301.0545	-1.337	2457301.0455	-0.661	2457301.0460	-0.350
2457301.0565	-1.330	2457301.0475	-0.652	2457301.0479	-0.339
2457301.0585	-1.342	2457301.0495	-0.655	2457301.0499	-0.343
2457301.0604	-1.336	2457301.0514	-0.660	2457301.0518	-0.344
2457301.0624	-1.328	2457301.0534	-0.666	2457301.0538	-0.347
2457301.0643	-1.336	2457301.0553	-0.654	2457301.0557	-0.345
2457301.0266	-1.328	2457301.0573	-0.647	2457301.0577	-0.339

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The full version is available on our website (http://binary.cbnu.ac.kr/).



Fig. 1. *V* light curves for UV Psc (top) and the differential magnitude between the comparison and check stars (bottom). The inset in the upper inner panel is a zoomed-in view of the primary eclipse curve. The black circles and red crosses represent data obtained before and after *HJD2457315*, respectively.

adjustable parameters were the initial epoch (T_0) , orbital period (P), inclination (i), temperature of the secondary component (T_2) , surface potentials $(\Omega_1 \text{ and } \Omega_2)$, relative luminosity of the primary component (l_1) , and third light (l_3) .

A cool spot was proposed as an explanation to interpret the distortion wave of the light curve, as suggested by Budding & Zeilik (1987), Han et al. (1996), Radhika & Vivekananda Rao (2001), Vivekananda Rao & Radhika (2002), and Kjurkchieva et al. (2005). To interpret the distortion wave in our light curves, we adopted the cool spot on the secondary component, but an appropriate model was not calculated. Therefore, an additional cool spot on the primary component was adopted because the primary component also has a convective envelope. The final WD

solution of UV Psc is listed in Table 3 and the synthetic BVR light curves are shown in the upper panel of Fig. 2 as solid lines. The spot radii of the primary and secondary components are 15.00 and 35.71 deg, indicating that both components are the sources of the distortion wave in UV Psc. The temperature of the secondary component is $T_2 =$ 4756 ± 4 K. The orbital inclination was modelled as i = 90.10 \pm 0.18 deg, implying that the line of sight is almost parallel to the orbital plane and UV Psc may have a retrograde orbit. From the *i*, the model light curves in Fig. 2 show the total eclipse at the secondary eclipse for approximately 27 min. The third light parameter l_3 was adjusted but not detected. To figure out the effect of the spots, theoretical light curves were calculated without considering the spots in Table 3 and are shown as dashed lines in the upper panel of Fig. 2. The residuals corresponding to presence and absence of the spots are plotted in the lower panel of Fig. 2 as the black and gray circles, respectively. Fig. 2 shows that the light depression from phase 0 to 0.3 was affected mainly by the cool spots, which existed actively on the surfaces of both components during the observation period.

To calculate the absolute parameters of UV Psc, we used the photometric solution in Table 3 and the semi-amplitude of the RV curves (K_1 and K_2) from Kjurkchieva et al. (2005). The masses, radii, and luminosities of both components

Table 3.	Light curve	parameters for	UV Psc
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Parameter	Primary	Secondary					
T_0 [HJD]	2452500	.0148 (56)					
P [day]	0.8610515(10)						
$q = M_2/M_1$	0.	733					
i [deg]	90.1	0 (18)					
Ω	4.828(3)	5.192(3)					
T[K]	5780	4756(4)					
$X_{ m bol}$	0.195	0.305					
$Y_{ m bol}$	0.520	0.383					
$L_1/L_{ m total,B}$	0.8807(10)	0.1193					
$L_1/L_{\rm total,V}$	0.8447 (9)	0.1553					
$L_1/L_{\rm total,R}$	0.8123 (9)	0.1877					
r _{volume}	0.2464	0.1815					
r _{pole}	0.2429(2)	0.1799(1)					
<i>r</i> _{point}	0.2513(2)	0.1838(1)					
r _{side}	0.2461 (2)	0.1812(1)					
<i>r</i> _{back}	0.2497 (2)	0.1832(1)					
Spot parameters:							
Co-Latitude θ [deg]	51.97 (52)	16.97 (31)					
Longitude λ [deg]	289.32 (34)	166.86 (1.51)					
Spot radius r _s [deg]	15.00 (9)	35.71 (24)					
Temperature factor T_s/T_*	0.796(4)	0.705 (23)					
$\Sigma W(O - C)^2$	0.00915						
Absolute parameters:							
$M[M_{\odot}]$	1.104 (42)	0.809 (82)					
$R[R_{\odot}]$	1.165 (25)	0.858(18)					
<i>L</i> [L _o]	1.361 (41)	0.339 (10)					



Fig. 2. *BVR* light curves of UV Psc (top) and residuals between the observation and model data (bottom). The black circles represent the observation data, and the gray circles in the bottom panel indicate the residuals for the non-spot model. The solid, dotted, and dashed lines represent the spot model, non-spot model, and zero lines, respectively. The blue, green, and red lines indicate the *BVR* filters.

were obtained as follows: $M_1 = 1.104 \pm 0.042$ and $M_2 = 0.809 \pm 0.082 \text{ M}_{\odot}$; $R_1 = 1.165 \pm 0.025$ and $R_2 = 0.858 \pm 0.018 \text{ R}_{\odot}$; and $L_1 = 1.361 \pm 0.041$ and $L_2 = 0.339 \pm 0.010 \text{ L}_{\odot}$, respectively. These values are similar to those reported by Popper (1997) and Kjurkchieva et al. (2005).

4. ORBITAL PERIOD VARIATION INVESTIGATION

To investigate the orbital period variation of UV Psc, we determined 17 times of minimum light (primary: 10, secondary: 7) from measurements by Han & Kim (1988), Heckert (2012), and CBNUOJ using Kwee & van Woerden (1956) method. We also collected the times of minimum light from previous studies, the O – C gateway (http://var. astro.cz/ocgate/), and the database compiled by Kreiner et al. (2000). The same epoch data collected from the same literature were calculated as a weighted mean value. All data used in this investigation are listed in Table 4. The eclipse timing diagram of UV Psc was calculated using Eq. (1) and is shown in Fig. 3, where the timings are differentiated by assorted symbols according to the observational method. From the diagram, the CCD and photoelectric (O - C) residuals after 1966 clearly varied in a continuously

Table 4. The times of minimum lights of UV Psc

HJD	Error	Me.1)	Type ²⁾	Epoch	Ref. ³⁾	HJD	Error	Me.1)	Type ²⁾	Epoch	Ref. ³⁾
2414666.490	-	Р	Ι	-43939.0	(1)	2429531.608	-	Р	Ι	-26675.0	(3)
2414981.630	-	Р	Ι	-43573.0	(1)	2429626.313	-	Р	Ι	-26565.0	(1)
2415372.539	-	Р	Ι	-43119.0	(1)	2429639.270	-	Р	Ι	-26550.0	(3)
2415434.532	-	Р	Ι	-43047.0	(1)	2429878.592	-	Р	Ι	-26272.0	(1)
2415668.769	-	Р	Ι	-42775.0	(1)	2429896.728	-	Р	Ι	-26251.0	(1)
2415763.479	-	Р	Ι	-42665.0	(1)	2429937.609	-	Р	II	-26203.5	(1)
2416059.660	-	Р	Ι	-42321.0	(1)	2430175.640	-	Р	Ι	-25927.0	(1)
2416134.584	-	Р	Ι	-42234.0	(1)	2430201.536	-	Р	Ι	-25897.0	(3)
2416746.774	-	Р	Ι	-41523.0	(1)	2430207.511	-	Р	Ι	-25890.0	(1)
2416859.545	-	Р	I	-41392.0	(1)	2430318.598	-	Р	T	-25761.0	(1)
2417212.630	-	P	I	-40982.0	(1)	2430648.377	-	P	ī	-25378.0	(1)
2417969 477	_	р	ī	-40103.0	(1)	2431358 734	_	р	ī	-24553.0	(1)
2418227 781	_	p	I	-39803.0	(1)	2431687 639	_	p	T	-24171.0	(1)
2410227.701		D	I	-39269.0	(1)	2431725 544		D	T	_24171.0	(1)
2410007.505		D	I	29905.0	(1)	2431723.344		D	T	24127.0	(1)
2419009.030	-	r D	I	-30033.0	(1)	2431730.401	-	г	T	-24112.0	(3)
2419003.703	-	г	I	-30112.0	(1)	2431043.247	-	г	T	-23300.0	(3)
2420404.303	-	r D	I	-37162.0	(1)	2432004.431	-	r	I	-22074.0	(1)
2420768.722	-	P	I	-36852.0	(1)	2432879.373	-	P	1	-22/8/.0	(1)
2421909.633	-	P	I	-35527.0	(1)	2432885.387	-	P	I	-22/80.0	(3)
2422621.712	-	P	I	-34700.0	(1)	2433888.484	-	P	I	-21615.0	(3)
2422993.710	-	Р	1	-34268.0	(1)	2433894.508	-	Р	1	-21608.0	(3)
2423327.731	-	Р	Ι	-33880.0	(1)	2433914.335	-	Р	Ι	-21585.0	(2)
2424134.574	-	Р	Ι	-32943.0	(1)	2433970.263	-	Р	Ι	-21520.0	(1)
2424165.546	-	Р	Ι	-32907.0	(1)	2434607.510	-	Р	Ι	-20780.0	(3)
2424789.796	-	Р	Ι	-32182.0	(1)	2435369.482	-	Р	Ι	-19895.0	(3)
2425527.755	-	Р	Ι	-31325.0	(1)	2435691.542	-	Р	Ι	-19521.0	(3)
2426678.503	-	Р	II	-29988.5	(1)	2436075.550	-	Р	Ι	-19075.0	(3)
2426985.525	-	Р	Ι	-29632.0	(2)	2436850.510	-	Р	Ι	-18175.0	(3)
2427004.430	-	Р	Ι	-29610.0	(2)	2439388.8736	-	PE	Ι	-15227.0	(4)
2427034.608	-	Р	Ι	-29575.0	(1)	2439406.9565	-	PE	Ι	-15206.0	(4)
2427061.293	-	Р	Ι	-29544.0	(3)	2439407.8167	-	PE	Ι	-15205.0	(4)
2427313.533	-	Р	Ι	-29251.0	(2)	2440466.9057	-	PE	Ι	-13975.0	(4), (5)
2427994.633	-	Р	Ι	-28460.0	(1)	2440854.351	-	VI	Ι	-13525.0	(6)
2428038.563	-	Р	Ι	-28409.0	(3)	2440860.4014	-	PE	Ι	-13518.0	(7)
2428067.798	-	Р	Ι	-28375.0	(1)	2440953.384	-	VI	Ι	-13410.0	(2)
2428080.735	-	Р	Ι	-28360.0	(1)	2441163.4933	-	PE	Ι	-13166.0	(8)
2428107.428	-	Р	Ι	-28329.0	(3)	2441276.281	-	VI	Ι	-13035.0	(9)
2428126.362	-	Р	Ι	-28307.0	(2)	2441282.304	-	VI	Ι	-13028.0	(9)
2428156.519	-	Р	Ι	-28272.0	(1)	2441301.250	-	VI	Ι	-13006.0	(10)
2428164.288	-	Р	Ι	-28263.0	(3)	2441319.340	-	VI	Ι	-12985.0	(10)
2428366.643	-	P	I	-28028.0	(1)	2441350.333	-	VI	T	-12949.0	(10)
2428373.499	-	P	I	-28020.0	(3)	2441534.609	-	VI	ī	-12735.0	(11)
2428373.546	-	P	I	-28020.0	(1)	2441565.610	-	VI	ī	-12699.0	(11)
2428398 464	_	р	I	-27991.0	(3)	2441571 630	_	VI	I	-12692.0	(11)
2428423 435	_	p	I	-27962.0	(3)	2441598 333	_	VI	T	-12661.0	(12)
2428429 502	_	p	I	-27955.0	(1)	2441610 374	_	VI	T	-12647.0	(12)
2420423.502		D	I	_27927.0	(1)	2441616.074		И	T	-12640.0	(12)
2420433.333	-	п	I	-27527.0	(3)	2441010.407	-	VI VЛ	T	12622.0	(12)
2420701.030	-	r D	I	-27509.0	(1)	2441022.455	-	VI VI	I	-12055.0	(12)
2428837.622	-	P	I	-27481.0	(1)	2441623.303	-	VI	1	-12032.0	(12)
2429110.557	-	P	1	-2/164.0	(3)	2441648.263	-	VI	1	-12603.0	(12)
2429156.647	-	P	11	-2/110.5	(1)	2441888.4942	-	PE	1	-12324.0	(13)
2429166.529	-	Р -	-	-27099.0	(3)	2441894.526	-	VI	1	-12317.0	(14)
2429230.243	-	Р	1	-27025.0	(3)	2441900.555	-	VI	1	-12310.0	(15)
2429267.275	-	Р	Ι	-26982.0	(1)	2441989.241	-	VI	Ι	-12207.0	(16)
2429486.859	-	Р	Ι	-26727.0	(1)	2442020.223	-	VI	Ι	-12171.0	(17)
2429514.403	-	Р	Ι	-26695.0	(3)	2442026.268	-	VI	Ι	-12164.0	(17)
2429514.420	-	Р	Ι	-26695.0	(1)	2442044.339	-	VI	I	-12143.0	(17)

Table 4. Co	ontinued
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		1)						n)	2)		
HJD	Error	Me. ¹⁾	Type ²⁾	Epoch	Ref. ³⁹	HJD	Error	Me. ¹⁾	Type ²⁾	Epoch	Ref. ³⁹
2442272.524	-	VI	Ι	-11878.0	(18)	2445323.214	-	VI	Ι	-8335.0	(42)
2442291.470	-	VI	Ι	-11856.0	(18)	2445335.266	-	VI	Ι	-8321.0	(42)
2442365.517	-	VI	Ι	-11770.0	(19)	2445341.300	-	VI	Ι	-8314.0	(2)
2442385.315	-	VI	Ι	-11747.0	(20)	2445613.392	-	VI	Ι	-7998.0	(43)
2442423.214	-	VI	Ι	-11703.0	(21)	2445632.332	-	VI	Ι	-7976.0	(43)
2442429.231	-	VI	Ι	-11696.0	(21)	2445681.410	-	VI	Ι	-7919.0	(2)
2442435.265	-	VI	Ι	-11689.0	(21)	2445987.5131	-	PE	II	-7563.5	(44)
2442680.663	-	VI	Ι	-11404.0	(22)	2446004.3008	-	PE	Ι	-7544.0	(44)
2442681.523	-	VI	Ι	-11403.0	(22)	2446023.250	-	VI	Ι	-7522.0	(45)
2442738.348	-	VI	Ι	-11337.0	(23)	2446043.0488*	0.0002	PE	Ι	-7499.0	(46)
2442738.353	-	VI	Ι	-11337.0	(22)	2446054.244	-	VI	Ι	-7486.0	(47)
2442776.240	-	VI	Ι	-11293.0	(24)	2446059.412	-	VI	Ι	-7480.0	(2)
2442782.262	-	VI	Ι	-11286.0	(25)	2446322.4592	-	PE	II	-7174.5	(44)
2442806.268	-	VI	Ι	-11258.0	(25)	2446326.3344	-	PE	Ι	-7170.0	(44)
2443041.442	-	VI	Ι	-10985.0	(26)	2446331.5004	-	PE	Ι	-7164.0	(44)
2443053.4926	0.0003	PE	Ι	-10971.0	(3), (27)	2446413.298	-	VI	Ι	-7069.0	(48)
2443079.3230	-	PE	Ι	-10941.0	(4)	2446745.2367	-	PE	II	-6683.5	(44)
2443080.1840	-	PE	Ι	-10940.0	(4)	2446753.4130	-	PE	Ι	-6674.0	(44)
2443123.2362	-	PE	Ι	-10890.0	(4)	2446760.305	-	VI	Ι	-6666.0	(49)
2443400.4951	0.0007	PE	Ι	-10568.0	(27)	2447057.365	-	VI	Ι	-6321.0	(50)
2443406.5225	0.0001	PE	Ι	-10561.0	(27)	2447082.329	-	VI	Ι	-6292.0	(50)
2443425.4660	0.0002	PE	I	-10539.0	(27)	2447094.3875	-	PE	I	-6278.0	(51)
2443428.4807	0.0004	PE	П	-10535.5	(3), (27)	2447113.326	-	VI	T	-6256.0	(52)
2443445.2691	-	PE	I	-10516.0	(4)	2447125.386	-	VI	T	-6242.0	(2)
2443446.1302	-	PE	I	-10515.0	(4)	2447410.3944	-	PE	T	-5911.0	(51)
2443452,1564	-	PE	I	-10508.0	(4)	2447434.5021	-	PE	T	-5883.0	(51)
2443463.3493	-	PE	I	-10495.0	(28)	2447553.328	-	VI	T	-5745.0	(53)
2443734.582	-	VI	I	-10180.0	(29)	2447856.4240	-	VI	T	-5393.0	(2)
2443772.471	-	VI	Ι	-10136.0	(30)	2448531.4756	-	PE	Ι	-4609.0	(54)
2443785.3834	0.0002	PE	Ι	-10121.0	(3), (27)	2448541.3770	-	PE	П	-4597.5	(54)
2443791.408	-	VI	Ι	-10114.0	(30)	2448594.3328	-	PE	Ι	-4536.0	(54)
2443803.472	-	VI	Ι	-10100.0	(30)	2448888.3754	0.0007	PE	II	-4194.5	(55)
2443805.1877	-	PE	Ι	-10098.0	(4)	2448897.4161	0.0007	PE	Ι	-4184.0	(55)
2443809.489	-	VI	Ι	-10093.0	(30)	2448913.3461	0.0006	PE	II	-4165.5	(55)
2443821.548	-	VI	Ι	-10079.0	(31)	2449003.330	-	VI	Ι	-4061.0	(56)
2443835.324	-	VI	Ι	-10063.0	(31)	2450003.4397	0.0013	PE	Π	-2899.5	(57)
2443841.345	-	VI	Ι	-10056.0	(31)	2450007.3112	0.0005	PE	Ι	-2895.0	(57)
2443848.241	-	VI	Ι	-10048.0	(32)	2450333.6434	0.0001	PE	Ι	-2516.0	(58)
2443849.0996	-	PE	Ι	-10047.0	(4)	2450334.5051	0.0002	PE	Ι	-2515.0	(58)
2443861.1542	-	PE	Ι	-10033.0	(4)	2450652.6656	0.0001	PE	II	-2145.5	(58)
2444144.445	-	VI	Ι	-9704.0	(33)	2450655.6767	0.0001	PE	Ι	-2142.0	(58)
2444157.345	-	VI	Ι	-9689.0	(33)	2450715.5266	0.0011	PE	II	-2072.5	(59)
2444168.551	-	VI	Ι	-9676.0	(2)	2450731.4506	0.0004	PE	Ι	-2054.0	(59)
2444201.275	-	VI	Ι	-9638.0	(33)	2450756.4201	0.0001	CCD	Ι	-2025.0	(60)
2444212.460	-	VI	Ι	-9625.0	(34)	2451031.9560*	0.0002	PE	Ι	-1705.0	(61)
2444225.3790	-	PE	Ι	-9610.0	(35)	2451397.9015*	0.0005	PE	Ι	-1280.0	(61)
2444603.386	-	VI	Ι	-9171.0	(36)	2451400.9157*	0.0002	PE	II	-1276.5	(61)
2444831.552	-	VI	Ι	-8906.0	(37)	2451403.9295*	0.0002	PE	Ι	-1273.0	(61)
2444869.447	-	VI	Ι	-8862.0	(2)	2451510.6989	-	PE	Ι	-1149.0	(62)
2444913.358	-	VI	Ι	-8811.0	(38)	2451523.6140	-	PE	Ι	-1134.0	(62)
2444913.363	-	VI	Ι	-8811.0	(38)	2451821.5362	0.0004	CCD	Ι	-788.0	(63)
2444931.438	-	VI	Ι	-8790.0	(38)	2452478.9453*	0.0005	PE	II	-24.5	(61)
2444932.2966	-	PE	Ι	-8789.0	(39)	2452607.6729	0.0001	CCD	Ι	125.0	(64)
2445241.415	-	VI	Ι	-8430.0	(40)	2452853.9313*	0.0003	PE	Ι	411.0	(61)
2445265.5228	-	PE	Ι	-8402.0	(41)	2452874.5969	0.0009	CCD	Ι	435.0	(65)
2445282.3144	-	PE	II	-8382.5	(41)	2452875.4627	-	VI	Ι	436.0	(66)
2445322.356	-	VI	Ι	-8336.0	(2)	2453225.9032*	0.0006	PE	Ι	843.0	(61)

HJD	Error	Me. ¹⁾	Type ²⁾	Epoch	Ref. ³⁾	HJD	Error	Me. ¹⁾	Type ²⁾	Epoch	Ref. ³⁾
2453228.9176*	0.0003	PE	II	846.5	(61)	2455483.5683	0.0008	CCD	Ι	3465.0	(74)
2453273.6972	0.0002	CCD	II	898.5	(67)	2455850.3760	0.0008	CCD	Ι	3891.0	(75)
2453283.5936	0.0003	CCD	Ι	910.0	(67)	2455889.9824	-	CCD	Ι	3937.0	(76)
2453286.6058	0.0010	CCD	II	913.5	(67)	2456152.6003	0.0004	CCD	Ι	4242.0	(77)
2453288.7592	0.0004	CCD	Ι	916.0	(67)	2456208.1410	-	CCD	II	4306.5	(78)
2453289.6211	0.0004	CCD	Ι	917.0	(67)	2456962.4148	0.0009	CCD	II	5182.5	(79)
2453294.7887	0.0006	CCD	Ι	923.0	(67)	2456974.0400	-	CCD	Ι	5196.0	(80)
2453298.6607	0.0006	CCD	II	927.5	(67)	2457287.4603	0.0002	CCD	Ι	5560.0	(81)
2453307.7029	0.0002	CCD	Ι	938.0	(67)	2457301.2381*	0.0001	CCD	Ι	5576.0	(82)
2453311.5756	0.0010	CCD	II	942.5	(67)	2457305.1121*	0.0002	CCD	II	5580.5	(82)
2453336.9771	-	CCD	Ι	972.0	(68)	2457308.1267*	0.0001	CCD	Ι	5584.0	(82)
2453953.9182*	0.0005	PE	II	1688.5	(61)	2457311.1406*	0.0006	CCD	II	5587.5	(82)
2453984.4866	0.0004	CCD	Ι	1724.0	(69)	2457326.2085*	0.0001	CCD	Ι	5605.0	(82)
2453990.5121	-	CCD	Ι	1731.0	(70)	2457327.0696*	0.0001	CCD	Ι	5606.0	(82)
2454040.0240	-	CCD	II	1788.5	(71)	2457330.0831*	0.0004	CCD	II	5609.5	(82)
2454097.2835	0.0013	CCD	Ι	1855.0	(66)	2457343.4300	0.0011	CCD	Ι	5625.0	(83)
2454369.3737	0.0002	CCD	Ι	2171.0	(72)	2457356.3420	0.0020	CCD	Ι	5640.0	(84)
2454845.9623	-	CCD	II	2724.5	(73)	2457677.0862	-	CCD	II	6012.5	(85)
2455143.0244	-	CCD	II	3069.5	(73)	2457682.6812	0.0010	CCD	Ι	6019.0	(86)

Table 4. Continued

* The times of minimum light newly calculated using photometric data from the literature.

¹⁾VI, visual; P, plate; PE, photoelectric; CCD, charge-coupled device.

²⁾ I, Primary time of minimum light; II, Secondary time of minimum light.

³⁾ (1) Strohmeier & Bauernfeind (1968), (2) Kreiner et al. (2000), (3) Hall & Kreiner (1980), (4) Vivekananda Rao & Sarma (1983b), (5) Oliver (1974), (6) Diethelm & Locher (1970), (7) Kizilirmak & Pohl (1971), (8) Pohl & Kizilirmak (1972), (9) Diethelm et al. (1972a), (10) Diethelm et al. (1972b), (11) Diethelm et al. (1972b), (12) Diethelm et al. (1972d), (13) Kizilirmak & Pohl (1974), (14) Diethelm et al. (1973a), (15) Aeberli et al. (1973), (16) Diethelm et al. (1973b), (17) Diethelm et al. (1974a), (18) Carnevali et al. (1974), (19) Diethelm et al. (1974b), (20) Carnevali et al. (1975b), (21) Carnevali et al. (1975b), (22) Baumann et al. (1975), (23) Isles (1976), (24) Diethelm et al. (1976), (25) Behagle et al. (1976), (26) Boninsegna et al. (1976b), (27) Aslan (1978), (28) Al-Naimiy et al. (1978), (29) Boninsegna et al. (1978), (30) Boninsegna et al. (1978), (31) Agnesoni et al. (1979), (32) Agnesoni et al. (1979), (33) Andrakakou et al. (1979), (34) Agnesoni et al. (1980), (35) Milano L. et al(1986), (36) Boistel et al. (1981), (37) Andrakakou et al. (1981a), (38) Andrakakou et al. (1981b), (39) Ibanoglu (1987), (40) Boistel et al. (1982), (41) Pohl et al (1983), (42) Diethelm et al. (1983), (43) Boninsegna et al. (1987), (50) Blanchart et al. (1987), (45) Boninsegna et al. (1988), (47) Boller et al. (1985), (48) Acerbi et al. (1986), (49) Blättler et al. (1987), (50) Blanchart et al. (1983), (51) Keskin & Pohl (1989), (52) Blättler et al. (1988), (53) Andrakakou et al. (1999), (50) Agerer et al. (1999), (51) Heckert (2012), (52) Sowell et al. (2003), (53) Selam et al. (1999), (60) Agerer et al. (1999), (51) Heckert (2012), (62) Sowell et al. (2007), (70) Csizmadia et al. (2000), (54) Negai (2007), (72) Liakos et al. (2007), (74) Zasche et al. (2008), (68) Nagai (2005), (69) Dogru et al. (2007), (70) Csizmadia et al. (2006), (71) Nagai (2007), (72) Liakos et al. (2014), (73) Nagai (2010), (74) Zasche et al. (2011), (75) Hübscher & Lemann (2012), (76) Nagai (2012), (77) Zasche et al. (2017)

decreasing pattern, although this pattern does not appear in the residuals for earlier plate timings because of their large short-term scattering. Therefore, we fitted all (O - C)residuals to a downward parabolic ephemeris using a leastsquare fitting method. The resultant ephemeris is as follows:

$$(O-C) = -0.^{d}38(\pm 3.65) \times 10^{-4} + 1.^{d}33(\pm 0.74) \times 10^{-7}E - 2.^{d}16(\pm 0.72) \times 10^{-11}E^{2}.$$
 (2)

In this calculation, the weights of plate (P), visual (VI), photoelectric (PE), and CCD measurements were assigned values of 0.01, 1, 10, and 10, respectively. The black dashed line in the first panel of Fig. 3 was drawn using Eq. (2), indicating that the equation is in good agreement with CCD and PE data. The second panel shows only the residuals ((O - C)_{res,1}) of PE and CCD timings from Eq. (2). The standard deviations from all timings and those from the PE and CCD

timings are $\sigma_{ALL,1} = 0.0144$ and $\sigma_{CCD,PE,1} = 0.0016$, respectively. The coefficient of quadratic term in Eq. (2) gives an orbital period decrease of $1.83(\pm 0.06) \times 10^{-8}$ days year⁻¹.

As mentioned in Section 1, Shengbang et al. (1999) proposed a cyclic orbital period variation. If we assume that the continuously decreasing variation in the (O - C) residuals of the PE and CCD timings in Fig. (3) is a part of a sinusoidal variation, the residuals could be fitted to a sine curve ephemeris using an iterative least-squares method. The equation was obtained as follows:

$$(O - C) = -0.^{d}89(\pm 1.55) \times 10^{-3} + 4.^{d}14(\pm 1.64) \times 10^{-7}E + 2.^{d}26(\pm 1.68) \times 10^{-3} \times \sin[2.74(\pm 0.66) + 2.03(\pm 1.12) \times 10^{-4}E].$$
 (3)

The blue solid curve in the first panel of Fig. 3 was generated from Eq. (3), and the residuals $((O - C)_{res,2})$ of the PE and CCD timings from Eq. (3) are shown in the bottom



Fig. 3. The eclipse timing diagram of UV Psc (top) and residuals of Eqs. (2) and (3) (middle and bottom). The black dashed line and blue solid line were plotted using Eqs. (2) and (3), respectively.

panel. The standard deviation of the $(O - C)_{res,2}$ ($\sigma_{CCD,PE,2}$) is the same as the $\sigma_{CCD,PE,1}$ of 0.0016 days, while the standard deviation of all timings was $\sigma_{ALL,2} = 0.0121$ day, slightly smaller than that of $\sigma_{ALL,1}$, which was 0.0144 day. Therefore, based on the present timing database, it is more acceptable that the orbital period of UV Psc exhibits a cyclic variation rather than a decreasing variation. The cyclic variation of the modulating period and amplitude were determined to be $P_{mod} = 73$ (±42) years and K = 2.3 (±1.7) × 10⁻³ days, respectively.

For completeness, we attempted to fit all (O - C) residuals to a combined ephemeris of a quadratic term and a sine curve ephemeris. However, we could not find any suitable solution for this case.

In general, the periodic (O - C) variation of UV Psc can be explained by the light time effect (LTE; Irwin 1952, 1959) caused by a circumbinary object or by the Applegatemechanism (Applegate 1992). If the third body in the UV Psc system causes of the (O - C) variation, its minimum mass is calculated to be $m_3 = 0.035 \text{ M}_{\odot}$ from the following mass function (Mayer 1990):

$$f(m_3) = \frac{m_3^3 \sin^3 i_3}{\left(M_1 + M_2 + m_3\right)^2} = \frac{\left(a_{12} \sin i_3\right)^3}{P_{mod}^2},$$
(4)

where a_{12} and i_3 are the semi-major axis of the center of mass of UV Psc and inclination of the third body, respectively. The calculated m_3 was much smaller than masses of the primary and secondary components, which is likely the reason why we could not detect l_3 in the light curve synthesis.

In contrast, assuming that the variation was caused by the Applegate-mechanism, the subsurface magnetic field strengths of the primary and secondary components were calculated to be 4.6 and 8.4 kG, respectively. These values are approximately twice the 2.0 and 4.6 kG of the primary and secondary components, respectively, predicted by Feiden & Chaboyer (2013) using the magnetic Dartmouth stellar evolution code. Therefore, it is reasonable to conclude that the periodic variation in the orbital period of UV Psc is caused by a circumbinary object.

5. SUMMARY AND CONCLUSION

BVR photometric observations of UV Psc were performed at CBNUOJ in 2015, and new light curves were obtained. The light curves varied on a short-term scale of less than a month, indicating that stellar activities are strong. The WD light curve synthesis suggested that the UV Psc is a typical RS CVn type system with $M_1 = 1.104 \pm 0.042$ M_{\odot}, $M_2 = 0.809$ \pm 0.082 M_o, R_1 = 1.165 \pm 0.025 R_o, R_2 = 0.858 \pm 0.018 R_o, L_1 = 1.361 \pm 0.041 $\rm L_{\odot}$, and $\rm L_2$ = 0.339 \pm 0.010 $\rm L_{\odot}.$ In addition, the eclipse timing diagram of UV Psc exhibited downward parabola variation. Our orbital period investigation showed that the downward parabola is part of the sinusoid and the LTE is more suitable than the AML and Applegatemechanism for interpreting the variation. However, since the UV Psc is an RS CVn type system, we cannot completely rule out a secular decrease of the orbital period caused by AML. Therefore, further observations of the times of minimum light and new light curves for this system are required to resolve the issues highlighted above.

ACKNOWLEDGMENTS

We appreciate the careful reading and helpful comments of the anonymous referees. We also would like to thank the staff at Jincheon station, Chungbuk National University Observatory. This work was supported by the National Research Foundation of Korea with grant numbers NRF-2014M1A3A3A02034746 and NRF-2017R1A4A1015178.

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REFERENCES

Acerbi F, Andrakakou M, Busquets J, Diethelm R, Germann R, et al., 112th List of minima of eclipsing binaries, BBSAG Bull. 79, 1-4 (1986).

- Acerbi F, Blättler E, Diethelm R, Locher K, Martignioni M, et al., 136th List of minima of eclipsing binaries, BBSAG Bull. 103, 1-7 (1993).
- Aeberli R, Boss U, Diethelm R, Forbes S, Germann R, et al., 44th Lists of minima of eclipsing binaries, BBSAG Bull. 11, 1-7 (1973).
- Agerer F, Dahm M, Hübscher J, Photoelectric minima of selected eclipsing binaries and maxima of pulsating stars, IBVS. 4712, 1-5 (1999).
- Agerer F, Hübscher J, Photoelectric minima of selected eclipsing binaries and maxima of pulsating stars, IBVS. 5296, 1-16 (2002).
- Agnesoni C, Andrakakou M, Boistel G, Buzzoni A, Diethelm R, et al., 79th List of minima of eclipsing binaries, BBSAG Bull. 46, 1-6 (1980).
- Agnesoni C, Berquet R, Boninsegna R, Buzzoni A, Clovin JP, et al., 74th List of minima of eclipsing binaries, BBSAG Bull. 41, 1-4 (1979).
- Albayrak B, Muyesseroglu Z, Ozdemir S, Photoelectric minima of some eclipsing binary stars, IBVS. 4941, 1-2 (2000).
- Al-Naimiy H, Budding E, Jassur D, Sadik AR, Observations of UV Psc and XY Cet, IBVS. 1415, 1-2 (1978).
- Andrakakou M, Blättler E, Busquets J, Boninsegna R, Bellas Y, et al., 124. List of minima of eclipsing binaries, BBSAG Bull. 91, 2-13 (1989).
- Andrakakou M, Boistel G, Boninsegna R, Diethelm R, Elias DP, et al., 89th List of minima of eclipsing binaries, BBSAG Bull. 56, 1-7 (1981a).
- Andrakakou M, Boistel G, Boninsegna R, Diethelm R, Elias DP, et al., 90th List of minima of eclipsing binaries, BBSAG Bull. 57, 1-5 (1981b).
- Andrakakou M, Buzzoni A, Diethelm R, Germann R, Locher K, et al., 78th List of minima of eclipsing binaries, BBSAG Bull. 45, 1-6 (1979).
- Antonopoulou E, Infrared photometry of the RS CVn binaries. III - JHK light curves of UV Psc, A&AS. 53, 347-349 (1983).
- Antonopoulou E, Infrared photometry of UV Piscium, Ap&SS. 135, 335-345 (1987) https://doi.org/10.1007/bf00641569
- Applegate JH, A mechanism for orbital period modulation in close binaries, ApJ. 385, 621-629 (1992) https://doi. org/10.1086/170967
- Aslan Z, Photoelectric times of minima and the period of UV Psc, IBVS. 1511, 1-4 (1978).
- Baumann M, Boninsegna R, Bourgeois J, Carnevali P, Clovin J-P, et al., 57th Lists of minima of eclipsing binaries, BBSAG Bull. 24, 1-6 (1975).
- Behagle M, Bininsegna R, Bourgeois J, Carnevali P, Clovin J-P, et al., 59th Lists of minima of eclipsing binaries, BBSAG Bull. 26, 1-6 (1976).
- Blanchart C, Blattler E, Boninsegna R, Dequinze R, Diethelm R.

et al., 119th List of minima of eclipsing binaries, BBSAG Bull. 86, 1-9 (1988).

Blattler E, Boistel G, Diethelm R, Germann R, Kohl M, et al., 121st List of minima of eclipsing binaries, BBSAG Bull. 88, 1-6 (1988).

Blattler E, Germann R, Hainaut V, Lambert S, Lheureux A, et al., 115th List of minima of eclipsing binaries, BBSAG Bull. 82, 1-5 (1987).

Boistel G, Boninsegna R, Diethelm R, Germann R, Locher K, et al., 85th List of minima of eclipsing binaries, BBSAG Bull. 52, 1-4 (1981).

Boistel G, Diethelm R, Elias DP, Germann R, Locher K, et al., 95th List of minima of eclipsing binaries, BBSAG Bull. 62, 1-5 (1982).

Boninsegna R, Buzzoni A, Carradori T, Clovin JP, Diethelm R, et al., 72nd Lists of minima of eclipsing binaries, BBSAG Bull. 39, 1-7 (1978).

Boninsegna R, Buzzoni A, Carradori T, Clovin JP, Diethelm R, et al., 73rd Lists of minima of eclipsing binaries, BBSAG Bull. 40, 1-3 (1978).

Boninsegna R, Clovin JP, Diethelm R, Doby P, Frangeul M, et al., 63rd Lists of minima of eclipsing binaries, BBSAG Bull. 30, 1-3 (1976b).

Boller A, Eyraud J, Germann R, Kohl M, Laternser M, et al., 108th List of minima of eclipsing binaries, BBSAG Bull. 75, 1-3 (1985).

Boninsegna R, Busquets J, Daratsakis C, Diethelm R, P.Elias D, et al., 102nd List of minima of eclipsing binaries, BBSAG Bull. 69, 1-6 (1983).

Boninsegna R, Diethelm R, Germann R, Ferrand S, Kohl M, et al., 107th List of minima of eclipsing binaries, BBSAG Bull. 74, 1-6 (1984).

Boninsegna R, Buzzoni A, Carradori T, Clovin JP, Diethelm R, et al., 71st List of minima of eclipsing binaries, BBSAG Bull. 38, 1-5 (1978).

Brat L, Zejda M, Svoboda P, B.R.N.O. Contributions #34, OEJV. 74, 1-75 (2007).

Budding E, Zeilik M, An analysis of the light curves of shortperiod RS Canum Venaticorum stars - starspots and fundamental properties, ApJ. 319, 827-835 (1987). https:// doi.org/10.1086/165500

Carnevali P, Diethelm R, Domec C, Figer A, Germann R, et al., 53rd Lists of minima of eclipsing binaries, BBSAG Bull. 20, 1-5 (1975b).

Carnevali P, Diethelm R, Figer A, Germann R, Locher K, et al., 50th Lists of minima of eclipsing binaries, BBSAG Bull. 17, 1-7 (1974).

Carnevali P, Diethelm R, Figer A, Germann R, Le Borgne J-F, et al., 52nd Lists of minima of eclipsing binaries, BBSAG Bull. 19, 1-4 (1975a).

- Csizmadia SZ, Klagyivik P, Borkovits T, Patkos L, Kelemen J, et al., New times of minima of some eclipsing binary systems, IBVS. 5736, 1-2 (2006).
- Deeg HJ, Doyle LR, Bejar VJS, Blue JE, Huver S, Minimum times of several eclipsing binaries, IBVS. 5470, 1-2, (2003).
- Diethelm R, Elias DP, Germann R, Kohl M, Locher K, et al., 97th List of minima of eclipsing binaries, BBSAG Bull. 64, 1-6 (1983).
- Diethelm R, Figer A, Germann R, Locher K, Peter H, et al., 58th Lists of minima of eclipsing binaries, BBSAG Bull. 25, 1-5 (1976).
- Diethelm R, Germann R, Giger M, Peter H, 39th Lists of minima of eclipsing binaries, BBSAG Bull. 6, 1-7 (1972d).

Diethelm R, Germann R, Giger M, Locher K, Peter H, et al.,38th Lists of minima of eclipsing binaries, BBSAG Bull. 5, 1-7 (1972c).

- Diethelm R, Germann R, Gliba G, Locher K, Mallama A, et al., 43rd Lists of minima of eclipsing binaries, BBSAG Bull, 10, 1-3 (1973a).
- Diethelm R, Figer A, Germann R, Locher K, Peter H, et al., List of minima of eclipsing binaries, BBSAG Bull. 18, 1-5 (1974b).
- Diethelm R, Germann R, Locher K, Peter H, 34th Lists of minima of eclipsing binaries, BBSAG Bull. 1, 1-5 (1972b).
- Diethelm R, Germann R, Locher K, Morger P, Peter H, et al., 45th Lists of minima of eclipsing binaries, BBSAG Bull. 12, 1-4 (1973b).

Diethelm R, Germann R, Locher K, Peter H, Wittwer H, 46th Lists of minima of eclipsing binaries, BBSAG Bull. 13, 1-5 (1974a).

- Diethelm R, Isles J, Locher K, Ergebnisse der beobachtungen von bedeckungsveranderlichen, Orion. 129, 60-61 (1972a).
- Diethelm R, Locher K, Resultats des observations d'etoiles variables a eclipse, Orion. 121, 191-192 (1970).

Dogru SS, Donmez A, Tuysuz M, New times of minima of some eclipsing binary stars, IBVS. 5746, 1-2 (2007).

Feiden GA, Chaboyer B, Magnetic inhibition of convection and the fundamental properties of low-mass stars. I. Stars with a Radiative Core, ApJ. 779, 183 (2013). https://doi. org/10.1088/0004-637X/779/2/183

Hall DS, The RS CVn Binaries and binaries with similar properties, ASSL. 60, 287-348 (1976) https://doi.org/10.1007/978-94-010-1175-4_15

- Hall DS, Kreiner JM, Shore SN, Period changes and mass loss rates in 34 RS CVn binaries, Acta Astron. 30, 387-451 (1980).
- Han W, Jeong MJ, Yoon JN, Woo KH, Kim Y, Apsidal motion study of close binary system CW cephei, JASS. 32, 341-348 (2015) https://doi.org/10.5140/JASS.2015.32.4.341
- Han W, Kim HI, Lee, WB, Orbital element analysis of a short period eclipsing binary UV piscium, JASS. 13, 72-78 (1996).
- Han WY, Kim TH, A photometric study of UV piscium, PASP. 100, 964-972 (1988) https://doi.org/10.1086/132258

Heckert PA, Two decades of optical photometry of short-period eclipsing RS CVn systems and other active chromosphere systems, JAD. 18, 1-16 (2012).

Høg E, Fabricius C, Makarov VV, Urban S, Corbin T, et al., The Tycho-2 catalogue of the 2.5 million brightest stars, A&A. 355, L27-L30 (2000).

Huth H. 1959, Mitt. Veränderl. Sterne. 424.

- Hübscher J, BAV-Results of observations Photoelectric minima of selected eclipsing binaries and maxima of pulsating stars, IBVS. 6196, 1-27 (2017) https://doi.org/10.22444/IBVS.6196
- Hübscher J, Lemann PB, BAV-Results of observations -Photoelectric minima of selected eclipsing binaries and maxima of pulsating stars, IBVS. 6026, 1-24 (2012).
- Ibanoglu C, The light curve variations in UV piscium, Ap&SS. 139, 139-147 (1987) https://doi.org/10.1007/BF00643819
- Irwin JB, The determination of a light-time orbit, ApJ. 116, 221-217 (1952) https://doi.org/10.1086/145604
- Irwin JB, Standard light-time curves, AJ. 64, 149-155 (1959) https://doi.org/10.1086/107913

Isles JE, Variable star section, JBAA. 86, 245-249 (1976).

Jassur DMZ, Kermani MH, UBV Photoelectric observations of UV piscium, IBVS. 3896, 1-4 (1993).

- Juryšek J, Hoňková K, Šmelcer L, Masek M, Lehky M, B.R.N.O. Contributions #40 Times of minima, OEJV. 179, 1-145 (2017).
- Keskin V, Pohl E, Photoelectric minima of eclipsing binaries, IBVS. 3355, 1-4 (1989).

Kim CH, Song MH, Yoon JN, Han W, Jeong MJ, BD Andromedae: A new short-period RS CVn eclipsing binary star with a distant tertiary body in a highly eccentric orbit, ApJ. 788, 134 (2014) https://doi.org/10.1088/0004-637X/788/2/134

Kizilirmak A, Pohl E, Photoelectric minima of eclipsing binaries, IBVS. 530, 1-4 (1971).

- Kizilirmak A, Pohl E, Photoelectric minima of eclipsing binaries, IBVS. 937, 1-7 (1974).
- Kjurkchieva DP, Marchev DV, Hechert PA, Ordway JI, Spectroscopic and photometric observations of the short-period RS CVn-type star UV Piscium, AJ. 129, 1084-1095 (2005) https:// doi.org/10.1086/427396
- Kreiner J, Kim CH, Nha IS, An Atlas of O-C Diagrams of Eclipsing Binary Stars (Wydawn. Nauk. Akad. Pedagogicznej, Krakow, Poland, 2000).

Kreiner JM, Up-to-date linear elements of eclipsing binaries, Acta Astron. 54, 207-210 (2004).

Kwee KK, van Woerden H, A method for computing accurately the epoch of minimum of an eclipsing variable, Bull. Astron. Inst. Netherlands. 12, 327-330 (1956).

- Liakos A, Gazeas K, Nanouris N, 105 minima timings of eclipsing binaries, IBVS. 6095, 1-4 (2014).
- Lucy LB, Gravity-darkening for stars with convective envelopes, Z. Astrophys. 65, 89-92 (1967).

- Mayer P, Eclipsing binaries with light-time effect, BAICz. 41, 231-236 (1990).
- Milano L, Mancuso S, Vittone A, D'Oris A, Marcozzi S, Observed photometric peculiarities of six eclipsing binaries with solar-type activity: I, Ap&SS. 124, 83-100 (1986) https://doi. org/10.1007/BF00649751
- Nagai K, Visual and CCD minima of eclipsing binaries during 2004, VSB. 43, 1-7 (2005).

Nagai K, Visual and CCD minima of eclipsing binaries during 2006, VSB. 45, 1-10 (2007).

- Nagai K, Visual and CCD minima of eclipsing binaries during 2009, VSB. 50, 1-10 (2010).
- Nagai K, Visual and CCD minima of eclipsing binaries during 2011, VSB. 53, 1-10 (2012).
- Nagai K, Visual and CCD minima of eclipsing binaries during 2012, VSB. 55, 1-10 (2013).
- Nagai K, Visual, CCD and DSLR minima of eclipsing binaries during 2014, VSB. 59, 1-9 (2015).
- Nagai K, Visual, CCD and DSLR minima of eclipsing binaries during 2016, VSB. 63, 1-9 (2017).
- Nelson RH, CCD minima for selected eclipsing binaries in 2002, IBVS. 5371, 1-4 (2003).
- Ogloza W, Niewiadomski W, Barnacka A, Biskup M, Malek K, et al., Times of minima observed by "Pi of the sky", IBVS. 5843, 1-6 (2008).
- Oliver JP, An investigation of eclipsing binary stars exhibiting calcium 2 emission, PhD Dissertation, LA, UCLA (1974).
- Paschke A, A list of minima and maxima timings, OEJV. 181, 1-12 (2015).
- Pohl E, Akan MC, Ibanoglu C, Sezer C, Gudur N, Photoelectric minima of eclipsing binaries, IBVS. 3078, 1-8 (1987).
- Pohl E, Hamzaoglu E, Gudur N, Ibanoglu C, Photoelectric minima of eclipsing binaries, IBVS. 2385, 1-6 (1983).
- Pohl E, Kizilirmak A, Photoelectric minima of eclipsing binaries, IBVS. 647, 1-3 (1972).
- Popper DM, Orbits of close binaries with Ca II H and K in emission. V - The main-sequence system UV Piscium, AJ. 102, 699-703 (1991) https://doi.org/10.1086/115904
- Popper DM, Orbits of detached main-sequence eclipsing binaries of types late F to K. II. UV Leonis, UV Piscium, and BH Virginis, AJ. 114, 1195-1205 (1997) https://doi. org/10.1086/118552

Radhika P, Vivekananda Rao P, Long-term study of the starspot activity on the eclipsing short-period RS Canum Venaticorum binary UV Piscium, BASI. 29, 317-322 (2001).

- Rucinski SM, The proximity effects in close binary systems. II. The bolometric reflection effect for stars with deep convective envelopes, Acta Astron. 19, 245-255 (1969).
- Shengbang Q, Qingtao L, Yulan Y, Orbital period studies of the RS CVn-type binaries II. UV Piscium, Ap&SS. 266, 529-538 (1999)

https://doi.org/10.1023/A:1002030722350

- Sadik AR, Light and colour curve observations and analysis of the short period eclipsing binary system UV PSC, Ap&SS. 63, 319-349 (1979) https://doi.org/10.1007/BF00638905
- Samolyk G, Recent Minima of 149 Eclipsing Binary Stars, J. Am. Var. Star. Obs. 43, 77-79 (2015).
- Samolyk G, Recent Minima of 298 Eclipsing Binary Stars, J. Am. Var. Star Obs. 45, 121-125 (2017).
- Selam SO, Gurol B, Muyesseroglu Z, Photoelectric times of minima of some eclipsing binary systems, IBVS. 4670, 1-3 (1999).
- Sowell JR, Hughes SB, Hall DS, Howard BA, Period changes in four short-period spotted binaries: UV Piscium, YY Geminorum, CG Cygni, and XY Ursae Majoris, AJ. 122, 1965-1973 (2001) https://doi.org/10.1086/323091
- Strohmeier W, Bauernfeind H, Perioden-kontrolle fur Bedeckungsveranderliche der Bamberger Liste, Bamberg Veroeffentlichungen der Remesis-Sternwarte. 7, 72 (1968).
- van Hamme W, New limb-darkening coefficients for modeling binary star light curves, AJ. 106, 2096-2117 (1993) https://doi. org/10.1086/116788
- Vivekananda Rao P, Radhika P, Long-term study of the starspot activity on the eclipsing short-period RS Canum Venaticorum star UV Piscium, Ap&SS. 282, 103-120 (2002)

https://doi.org/10.1023/A:1021194218533

- Vivekananda Rao P, Sarma MBK, Photoelectric observations of UV Pisces, Contrib. Nizamiah Japal-Rangapur Obs. 14, 62 (1981).
- Vivekananda Rao P, Sarma MBK, The distortion wave on the light curve of the RS CVn binary UV Piscium, J. Astrophys. Astr. 4, 161-169 (1983a).
- Vivekananda Rao P, Sarma MBK, Period study of the short period RS CVn type eclipsing binary UV Piscium, BASI. 11, 75-81 (1983b).
- Wilson RE, Devinney EJ, Realization of accurate close-binary light curves: Application to MR Cygni, ApJ. 166, 605-619 (1971) https://doi.org/10.1086/150986
- Wunder E, Wieck M, Kilinc B, Gulmen O, Tunca Z, New photoelectric minima of some eclipsing binaries, IBVS. 3760, 1-3 (1992).
- Zasche P, Uhlar R, Kucakova H, Svoboda P, Collection of minima, IBVS. 6007, 1-12 (2011).
- Zasche P, Uhlar R, Kucakova H, Svoboda P, Masek M, Collection of minima of eclipsing binaries, IBVS. 6114, 1-19 (2014).
- Zeilik M, Elston R, Henson G, Schmolke P, Smith P, 1981 UBVR photometry of UV Psc, IBVS. 2089, 1-4 (1982).
- Zejda M, CCD Times of minima of selected eclipsing binaries, IBVS. 5583, 1-15 (2004).