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New CCD photometric investigation of the early-type overcontact binary BH Cen in the young star-forming Galactic cluster IC 2944

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Abstract BH Cen is a short-period early-type binary with a period of $0.792^{\rm d}$ in the extremely young star-forming cluster IC 2944. New multi-color CCD photometric light curves in U, B, V, R and I bands are presented and are analyzed by using the Wilson-Devinney code. It is detected that BH Cen is a high-mass-ratio overcontact binary with a fill-out factor of 46.4% and a mass ratio of 0.89. The derived orbital inclination i is 88.9 degrees, indicating that it is a totally eclipsing binary and the photometric parameters can be determined reliably. By adding new eclipse times, the orbital period changes in the binary are analyzed. It is confirmed that the period of BH Cen shows a long-term increase while it undergoes a cyclic oscillation with an amplitude of $A_3 = 0.024$ d and a period of $P_3 = 50.3$ yr. The high mass ratio, overcontact configuration and long-term continuous increase in the orbital period all suggest that BH Cen is in the evolutionary state after the shortest-period stage of Case A mass transfer. The continuous increase in period can be explained by mass transfer from the secondary component to the primary one at a rate of $\dot{M}_2 = 2.8 \times 10^{-6}\, M_\odot$ per year. The cyclic change can be plausibly explained by the presence of a third body because both components in the BH Cen system are early-type stars. Its mass is determined to be no less than $2.2\, M_\odot$ at an orbital separation of about 32.5 AU. Since no third light was found during the photometric solution, it is possible that the third body may be a candidate for a compact object.

Key words: binary (including multiple): close — stars: binaries: eclipsing — stars: early-type — stars: evolution — stars: individual (BH Cen)

1 INTRODUCTION

BH Centauri (HD 208826, GSC 08976–00547) is a short-period contact binary that is a member of the extremely young Galactic cluster IC 2944. It was found to be a variable star with a period of $0.7915814^{\rm d}$ by Oosterhoff (1928, 1930), based on photographic observations. Leung & Schneider (1977) obtained photoelectric light curves in UBV bands for the first time and analyzed the light curves by using the Wilson-Devinney (W-D) code (Wilson & Devinney 1971) and they also provided a revised period. Then, Sistero et al. (1983) obtained more reliable light curves without large scatter. Leung et al. (1984) analyzed the light curves and found that the degree of overcontact in this system is 48% and the mass ratio is 0.84. They also estimated the absolute parameters of the binary system by considering its membership in the young Galactic cluster IC 2944. The orbital period change has been discussed by several authors in the last century and many of them confirmed that the period of BH Cen is variable. Qian et al. (2006) discovered that the orbital period of BH Cen undergoes a long-term increase at a rate of $+1.7 \times 10^{-7}$ d yr^{-1} with a cyclic change of 44.6 yr.

BH Cen is one of a small group of early-type close binaries with period of less than one day. Some other examples include V701 Sco (Bell & Malcolm 1987), RZ Pyx (Zhao & Qian 2011), CT Tau (Plewa & Wlodarczyk 1993), V593 Cen (Lapasset et al. 1988) and V758 Cen (Lipari & Sistero 1985). They are more massive than their cooler cousins, i.e., W UMa-type contact binary stars. The components in the latter type of binaries are FGK-type stars with a typical period of about $P = 0.29$ d (Qian et al. 2017). Investigation of the small group of early-type short-period binaries would provide valuable information on the evolutionary state of close binary systems. In this paper, multi-color CCD photometric light curves in $UBVRI$ bands are presented, then the orbital period variations and new photometric data of BH Cen are reanalyzed. Finally, based on the period changes and photometric properties, the triplicity, and the formation and evolutionary states of the binary are investigated.

2 NEW OBSERVATIONS AND PERIOD ANALYSIS OF BH CEN

The first photoelectric light curves for BH Cen in UBV bands were presented and analyzed by Sistero et al. (1983) and Leung & Schneider (1977). From figure 1 of Leung & Schneider (1977), we can see that there were large scatters in all three bands. Subsequently, Leung et al. (1984) reduced the number of points in these light curves and updated the analysis. From that time when the latest light curves were analyzed, more than thirty years have passed. In order to reanalyze more accurate light curves and period changes associated with this binary star, new complete light curves and minimum times were observed during six nights from 2016 April 25 to May 3 by using a 1024×1024 pixel CCD (designated as STE4) attached to the 1-m telescope at South African Astronomical Observatory, which has a Cassegrain design and f-ratio of 16. During these observations, the filters we used are like the same as a standard Bessel system. When reducing the observed images, the pipeline based on the DoPHOT package of IRAF was adopted. The coordinates of the comparison star (TYC 8976-27-1) are $\alpha = 11^{\rm h}39^{\rm m}21.538^{\rm s}$, $\beta = -63°26' \, 28.04''$, which can be seen in Figure 1.

The new multi-color light curves are plotted in Figure 2, which are in phase and calculated with the epoch HJD $2457509.3106 + 0.7915852^{\rm d} \times E$ and the data are listed in tables in the Appendix.

All of the available photographic, photoelectric and CCD times of light minimum were collected and are listed in Table 1. The third column displays the methods, where "pg" refers to photographic, "pe" to photoelectric and "CCD" to charge-coupled device. The $(O-C)_1$ curve of BH Cen was derived by using the linear ephemeris from the General Catalog of Variable Stars (GCVS),

$$\mathrm{Min\,I} = 2431748.7478 + 0.79158298^{\rm d} \times E. \quad (1)$$

The $(O-C)_1$ value is listed in the fifth column of Table 1 and the corresponding $(O-C)_1$ diagram is plotted against epoch number in the upper panel of Figure 3. It is obvious that the orbital period of BH Cen is variable. As demonstrated in the upper panel of Figure 3, the general trend of $(O-C)_1$ shows an upward parabolic change (dashed line), indicating that the period is continuously increasing. However, after the long-term continuous increase was removed from the $(O-C)_1$ curve, we found there is also a cyclic oscillation in the residuals. Therefore, a cyclic term is added to a quadratic ephemeris to fit the observations (solid line in the upper of Fig. 3). With weight 1 applied to photographic data and weight 8 applied to photoelectric and CCD observations, a least-squares solution leads to the following ephemeris,

$$\begin{aligned}\mathrm{Min\,I} \;=\; & 2438431.7306 + 0.7915822^{\rm d}(2) \times E \\ & +1.37(9) \times 10^{-10} \times E^2 \\ & +0.024(3)\sin\Big[0.0155° \times E \\ & +553.°(9.5°)\Big]. \quad (2)\end{aligned}$$

The quadratic term in the ephemeris (dashed line in Fig. 3) represents a continuous period increase at a rate of $dP/dt = 1.26(0.08) \times 10^{-7}$ d yr^{-1}, which is equivalent to a period increase of 1.1 s per century. Residuals from the equation are exhibited in the lower panel of Figure 3. The sinusoidal term in Equation (2) reveals cyclic change where period is $P_3 = 50.3$ yr with an amplitude of $A_3 = 0.024$ d, which is more easily seen in the middle panel of Figure 3.

3 PHOTOMETRIC SOLUTIONS

During recent decades, the W-D code has undergone many changes (Wilson & Devinney 1971; Wilson 1990,

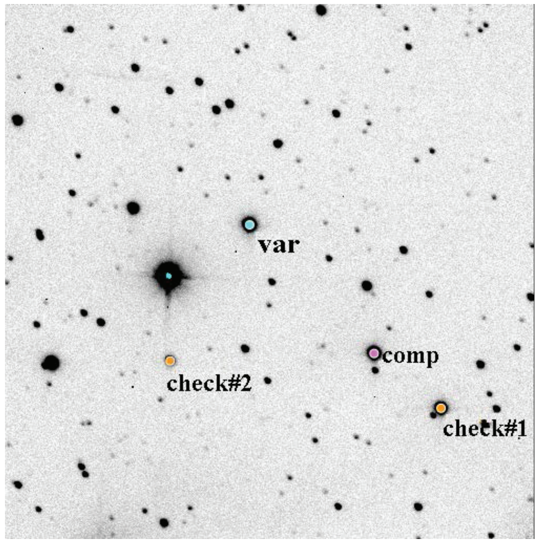

Fig. 1 The finding chart of BH Cen. var represents the target BH Cen while $comp$ refers to the comparison star TYC 8976-27-1.

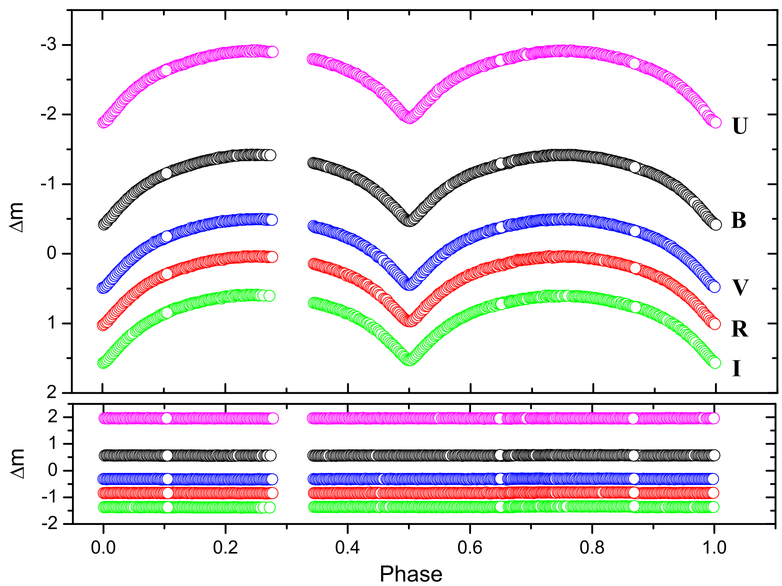

Fig. 2 The multi-color light curves of BH Cen. *Upper*: Different colors from top to bottom represent the difference between BH Cen and comparisons in $UBVRI$ bands. *Bottom*: Difference between comparison and check star (check #1 in Fig. 1).

1994; van Hamme & Wilson 2003; Wilson 2012 and so on). The new $UBVRI$ multi-color light curves are analyzed with the latest version of the W-D code. We applied effective temperature of the primary, $T_1 = 17\,900\,\mathrm{K}$, which is the same as what Leung et al. (1984) determined. There was no mass ratio from spectral observation before, so we used the q-search method to find an initial mass ratio. We fixed mass ratio (q) at a series of values from 0.7 to 1.5 and then found convergent solutions at each value, which is illustrated in Figure 4. From the relation between q and residuals ($\Sigma(O-C)^2$), the lowest and optimal value for mass ratio should be $q = 0.88$. Then, we set q as a free parameter and obtained the final solutions. During the whole process, the gravity-darkening coefficients $g_1 = g_2 = 1.0$ (Lucy 1967) and the bolometric albedos $A_1 = A_2 = 1.0$ (Ruciński 1969) were adopted. The contact model (model 3) was chosen and the adjustable parameters are listed as follows: mass ratio q; orbital inclination i; temperature of secondary T_2; luminosity of primary component and so on. The photo-

Table 1 All Available Light Minima for BH Cen

HJD 2400000+	Error (d)	Method	E	$(O-C)_1$ (d)	Reference
22084.2970	–	pg	−12209	−0.0142	Sistero et al. (1979)
25025.4340	–	pg	−8493.5	−0.0038	Sistero et al. (1979)
25329.4080	–	pg	−8109.5	0.0024	Sistero et al. (1979)
25331.3920	–	pg	−8107	0.0074	Sistero et al. (1979)
25351.5360	–	pg	−8081.5	−0.0339	Sistero et al. (1979)
25362.2670	–	pg	−8068	0.0107	Sistero et al. (1979)
25385.2280	–	pg	−8039	0.0158	Sistero et al. (1979)
25386.4040	–	pg	−8037.5	0.0044	Sistero et al. (1979)
25404.2090	–	pg	−8015	−0.0012	Sistero et al. (1979)
25714.4970	–	pg	−7623	−0.0137	Sistero et al. (1979)
31748.7478	–	pg	0	0	Sistero et al. (1979)
39621.7975	0.0015	pe	9946	−0.0346	Sistero et al. (1979)
43987.8119	0.0008	pe	15461.5	0.0039	Sistero et al. (1979)
43989.7917	0.0005	pe	15464	0.0047	Sistero et al. (1979)
43990.5835	0.0004	pe	15465	0.0049	Sistero et al. (1979)
44028.5796	0.0004	pe	15513	0.0050	Sistero et al. (1979)
44095.4693	0.0005	pe	15597.5	0.0060	Sistero et al. (1979)
44280.7071	–	pe	15831.5	0.0134	Herczeg (1984)
44429.5212	–	pe	16019.5	0.0099	Herczeg (1984)
44679.6663	0.0004	pe	16335.5	0.0147	Herczeg (1984)
44681.6453	0.0004	pe	16338	0.0148	Herczeg (1984)
45908.2209	0.0001	pe	17887.5	0.0325	Pfleiderer & Pfleiderer (1985)
51928.2360	–	pe	25492.5	0.0591	*http://var2.astro.cz/ocgate/*
51984.4364	–	pe	25563.5	0.0571	Qian et al. (2006)
51985.6271	–	CCD	25565	0.0604	Qian et al. (2006)
53074.0536	–	CCD	26940	0.0603	Qian et al. (2006)
53074.4499	–	CCD	26940.5	0.0608	Qian et al. (2006)
54252.3240	0.002	CCD	28428.5	0.0595	Paschke (2007)
57507.33175	0.00015	CCD	32540.5	0.07799	this paper
57509.31060	0.00018	CCD	32543	0.0779	this paper

metric solutions are provided in Table 2 and the theoretical light curves computed with these photometric elements are plotted in Figure 5. The geometrical structures (phases 0 and 0.25) of BH Cen are displayed in Figure 6 which reveal that BH Cen is a totally eclipsing system.

4 DISCUSSION AND CONCLUSIONS

We analyzed the complete U, B, V, R and I light curves of BH Cen by using the W-D code and obtained the photometric solutions. Based on these solutions, the mass ratio of the system (M_2/M_1) is determined to be 0.885, orbital inclination i is 88.9 degrees, temperature of the secondary is nearly the same as that of the primary and the fill-out factor is about 46.4%. From the new solutions, the system is identified as an overcontact binary. The increase in secular period deduced from the $O-C$ analysis can be interpreted by mass transfer from the less massive component to the more massive one. Using the well-known equation that considers conservation in the system,

$$\frac{\dot{P}}{P} = 3\dot{M}_2\Big(\frac{1}{M_1} - \frac{1}{M_2}\Big), \quad (3)$$

the mass transfer can be calculated to be $\dot{M}_2 = 2.8 \times 10^{-6}\ M_\odot$ per year by assuming the mass is the same as in Leung et al. (1984). This indicates the binary is now undergoing Case A mass transfer. The contact configuration will be broken by mass transfer from the less massive component to the more massive one, just like in LY Aur (Zhao et al. 2014), V382 Cyg and TU Mus (Qian et al. 2007), which confirms the conclusion that an early-type contact binary stays in a Case A overcontact configuration during its evolution for a short time (Sybesma 1985, 1986). We can propose a scenario that leads to the formation of a binary system like BH Cen. At first, the more massive component of the binary system evolves to fill out its Roche lobe and lose mass to the secondary

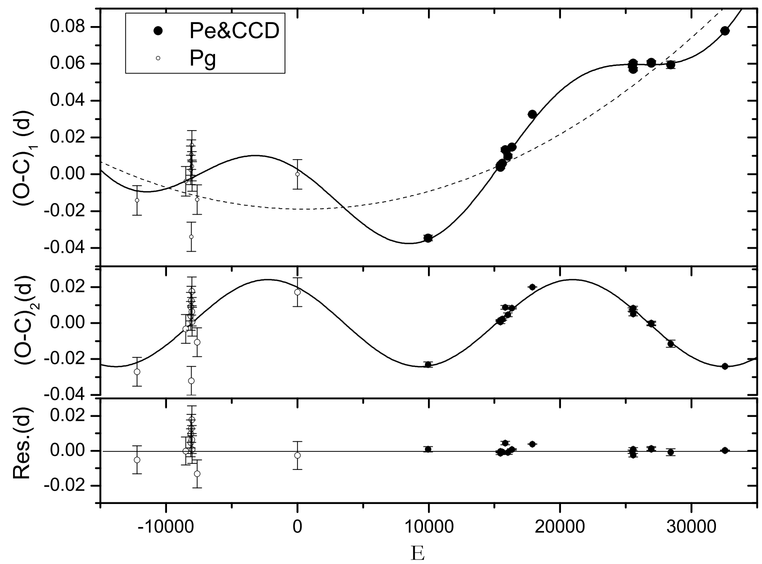

Fig. 3 $O - C$ curves of BH Cen. *Solid circles* represent minimum times observed by photoelectric and CCD photometry and *open circles* refer to photographic data. We used error "0.008" for "pg" data and "0.001" for some of "pe" and "CCD" data which have no intrinsic errors. *Upper*: The *dashed line* is the quadratic term of Equation (2) and the *solid line* is the long-term change with cyclic oscillation. *Middle*: $(O-C)_2$ is generated by removing the long-term increase and the *solid line* is the cyclic change. *Bottom*: Residuals after removing the long-term and periodic variations.

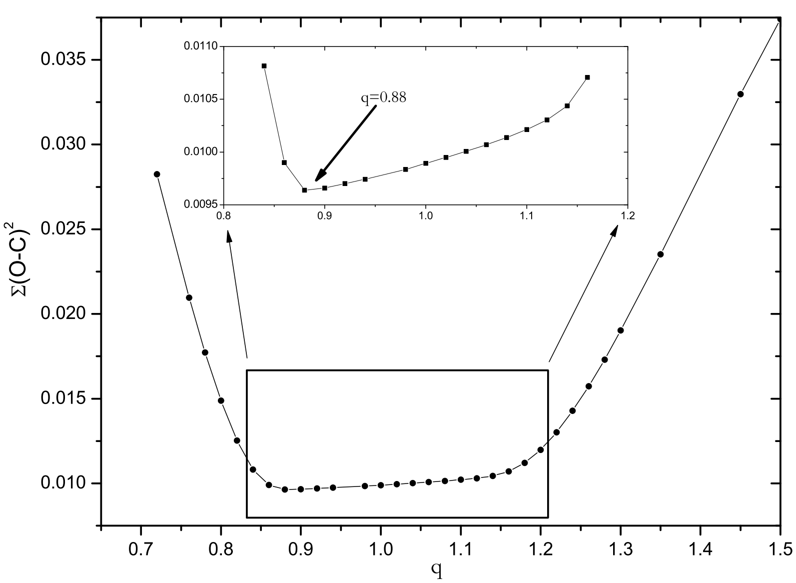

Fig. 4 Mass ratio search using new light curves of BH Cen.

component. Along with the mass transfer, the mass ratio increases while the system's period and distance between two the components decreases. As time goes on, the system becomes a contact binary. When the mass ratio is equal to one, the system has the shortest period and shortest distance. Afterwards, the mass transfer does not stop, and the original primary becomes the less massive component. At the same time, the period of the system and distance between primary and secondary increase, just like the current state of BH Cen with a high-mass-ratio

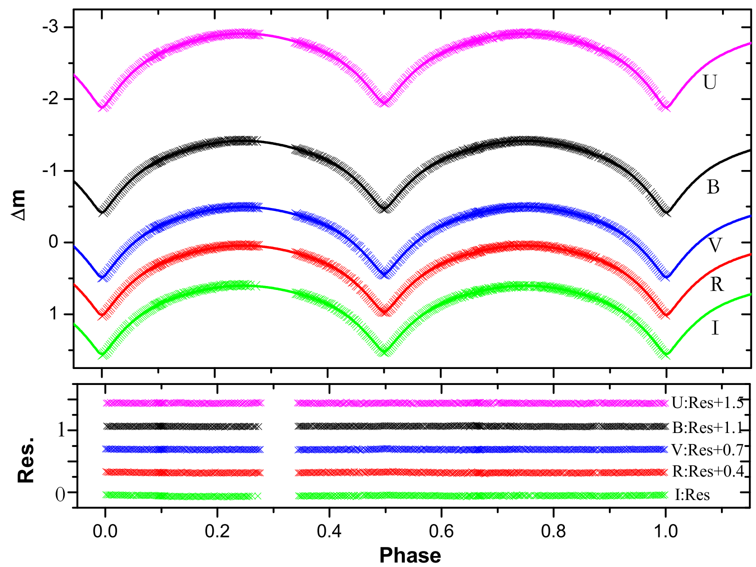

Fig. 5 Theoretical light curves (*solid lines*) calculated by using the W-D method. The *crosses* in different colors represent observations in different bands. Below the light curves are the residuals, which are computed by removing the theoretical light curves.

Table 2 The Solutions of BH Cen by Using the W-D Code

Parameters	Model 3
g_1 (fix)	1.0
g_2 (fix)	1.0
A_1 (fix)	1.0
A_2 (fix)	1.0
T_1 (fix)	17 900 K
$q\,(M_2/M_1)$	0.885
T_2	17506±55 K
i	88.93±0.06
$L_1/(L_1+L_2)_U$	0.5393±0.0003
$L_1/(L_1+L_2)_B$	0.5357±0.0003
$L_1/(L_1+L_2)_V$	0.5347±0.0004
$L_1/(L_1+L_2)_R$	0.5341±0.0005
$L_1/(L_1+L_2)_I$	0.5335±0.0008
$\Omega_1=\Omega_2$	3.333
r_1 (pole)	0.3982 ± 0.0003
r_1 (side)	0.4259 ± 0.0003
r_1 (back)	0.4766 ± 0.0004
r_2 (pole)	0.3782 ± 0.0011
r_2 (side)	0.4032 ± 0.0014
r_2 (back)	0.4574 ± 0.0027
filling (%)	46.4 ± 0.8
$\sum(O-C)_i^2$	9.13×10^{-3}

and long-term increase in orbital period. Along with the continuous mass transfer, the contact configuration will be disrupted.

Besides the long-term period increase, there is also a periodic change in Figure 3. BH Cen is composed of two early-type component stars that presumably contain a convective core and a radiative envelope. This suggests that the periodic oscillation cannot be explained by the magnetic activity cycle mechanism, which is usually proposed to explain the cyclic period change of solar-type binary stars (e.g. Applegate 1992; Lanza et al. 1998). Therefore, the light-travel time effect via the presence of a tertiary component is used to explain the periodic change in the orbital period (e.g. Borkovits & Hegedues 1996; Chambliss 1992). By considering that a third body is rotating in a circular orbit, the projected radius of the orbit $a'_{12}\sin i'$ of the eclipsing pair moving around the center of mass of the triple system can be computed with the equation,

$$a'_{12}\sin i' = A_3\times c\,, \qquad (4)$$

where A_3 is the amplitude of the $O-C$ oscillation and c is the speed of light. Then by utilizing the parameter derived by Leung et al. (1984), a calculation with the following equation,

$$f(m)=\frac{4\pi^2}{GP_3^2}\times(a'_{12}\sin i')^3, \qquad (5)$$

leads to a mass function of $f(m)=0.028(0.011)\,M_\odot$. In Equation (5), G and P_3 are the gravitational constant

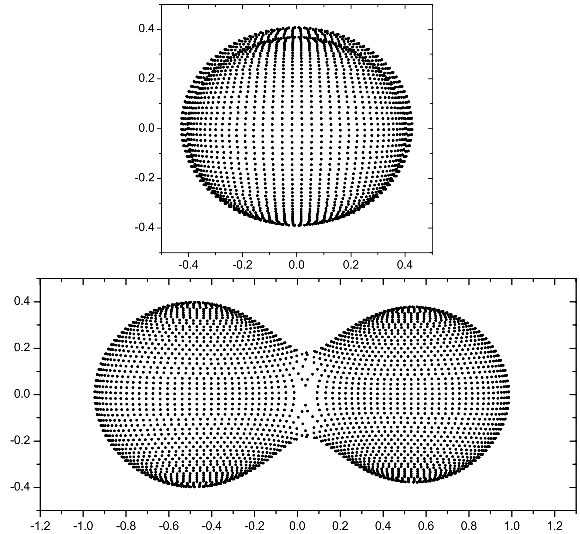

Fig. 6 Geometrical structure of BH Cen at phases 0 and 0.25.

and period of the $O-C$ oscillation respectively. Finally, values of the masses and orbital radii of the third components are estimated by applying the following equation,

$$f(m) = \frac{(M_3 \sin i')^3}{(M_1 + M_2 + M_3)^2}. \quad (6)$$

It is calculated that the lowest mass of the additional body is $2.2(\pm 0.3)\,M_\odot$ and the separation between the binary and the tertiary companion is shorter than $32.5(6.0)$ AU. Usually, an additional body is large enough to contribute to light from the system, but when we try to solve the light curves with a third light l_3, the resulting l_3 is always negative. An additional body with star-like mass but no light may be a candidate for a neutron star or black hole. This kind of tertiary body is familiar to many other massive close binary stars, e.g., V701 Sco (Qian et al. 2006), V382 Cyg, TU Mus (Qian et al. 2007) and AI Cru (Zhao et al. 2010). To confirm the period increase and periodic oscillation of BH Cen, mass ratio from spectral observation and more photometry observations are urgently required.

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Appendix A: NEW DATA OF BH CEN

Table A.1 New Data on BH Cen in the U Band

Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm
0.00161	−1.88634	0.11697	−2.68304	0.24349	−2.92063	0.43297	−2.47281	0.56188	−2.44711	0.67536	−2.83299	0.79855	−2.8778	0.92618	−2.50909
0.00406	−1.89643	0.1194	−2.69724	0.24592	−2.91587	0.43539	−2.45778	0.56431	−2.45749	0.6775	−2.84682	0.801	−2.87893	0.92862	−2.48937
0.00648	−1.92471	0.12184	−2.70452	0.24836	−2.90502	0.43782	−2.43426	0.56675	−2.47552	0.67962	−2.84128	0.80345	−2.88566	0.93105	−2.46541
0.00892	−1.93297	0.12427	−2.70959	0.25078	−2.92156	0.44026	−2.42438	0.56918	−2.49237	0.68175	−2.85475	0.8059	−2.8756	0.93348	−2.46099
0.01135	−1.97502	0.12669	−2.70943	0.25323	−2.90834	0.44269	−2.41447	0.57162	−2.4978	0.68387	−2.86267	0.80834	−2.8752	0.93592	−2.44278
0.01379	−1.99135	0.12913	−2.71785	0.25565	−2.91967	0.44512	−2.40212	0.57405	−2.51895	0.68601	−2.85743	0.81079	−2.86294	0.93835	−2.42729
0.01622	−2.02125	0.13156	−2.72454	0.2581	−2.91566	0.44756	−2.38369	0.57647	−2.52608	0.68813	−2.87703	0.81324	−2.86361	0.94079	−2.40837
0.01866	−2.04493	0.134	−2.72715	0.26052	−2.90566	0.44998	−2.36891	0.57892	−2.54384	0.69026	−2.85992	0.81568	−2.85475	0.94322	−2.37979
0.02109	−2.06233	0.13643	−2.74041	0.26295	−2.91045	0.45241	−2.34991	0.58134	−2.54972	0.69238	−2.85747	0.81814	−2.85615	0.94566	−2.37976
0.02352	−2.10134	0.13887	−2.75263	0.26539	−2.90382	0.45485	−2.31395	0.58377	−2.55851	0.69876	−2.87289	0.82058	−2.84589	0.94808	−2.35154
0.02596	−2.11495	0.1413	−2.75746	0.26782	−2.90317	0.45728	−2.29755	0.58621	−2.58002	0.70089	−2.87265	0.82304	−2.84619	0.95051	−2.33741
0.02838	−2.14295	0.14373	−2.75999	0.27026	−2.89628	0.45972	−2.29462	0.58864	−2.59282	0.70301	−2.87254	0.82548	−2.83926	0.95295	−2.32427
0.03083	−2.1714	0.14617	−2.77111	0.27269	−2.89703	0.46215	−2.27071	0.59108	−2.59058	0.70515	−2.88285	0.82792	−2.83054	0.95538	−2.29491
0.03325	−2.19488	0.1486	−2.78173	0.27511	−2.90285	0.46458	−2.2411	0.59351	−2.60147	0.70727	−2.89153	0.83038	−2.83535	0.95782	−2.27333
0.0357	−2.22074	0.15104	−2.78368	0.27756	−2.90097	0.46702	−2.21396	0.59594	−2.6164	0.7094	−2.89391	0.83282	−2.82011	0.96025	−2.25858
0.03812	−2.2374	0.15346	−2.79065	0.34296	−2.79657	0.46945	−2.20144	0.59838	−2.63555	0.71152	−2.89586	0.83528	−2.81849	0.96268	−2.24113
0.04055	−2.26679	0.15589	−2.80393	0.34538	−2.79622	0.47187	−2.18193	0.6008	−2.63436	0.71364	−2.89521	0.83772	−2.81848	0.96512	−2.21796
0.04299	−2.27762	0.15833	−2.80445	0.34783	−2.78427	0.47431	−2.15498	0.60323	−2.64264	0.71578	−2.89457	0.84016	−2.8179	0.96755	−2.19114
0.04542	−2.29417	0.16076	−2.81476	0.35025	−2.78686	0.47674	−2.12656	0.60567	−2.65437	0.7179	−2.89734	0.84262	−2.79573	0.96999	−2.16807
0.04786	−2.32231	0.1632	−2.80376	0.35268	−2.77538	0.47917	−2.11515	0.6081	−2.65754	0.72003	−2.89419	0.84506	−2.79363	0.97241	−2.14457
0.05029	−2.3453	0.16563	−2.82087	0.35512	−2.77157	0.48161	−2.08493	0.61054	−2.67237	0.72215	−2.90486	0.84751	−2.79618	0.97486	−2.12212
0.05273	−2.35957	0.16806	−2.82524	0.35755	−2.76554	0.48404	−2.06235	0.61297	−2.68013	0.72429	−2.90147	0.84996	−2.79342	0.97728	−2.09908
0.05516	−2.38285	0.1705	−2.83154	0.35998	−2.76512	0.48648	−2.03663	0.6154	−2.69272	0.72641	−2.9092	0.85241	−2.78324	0.97973	−2.06293
0.0576	−2.40098	0.17293	−2.83577	0.36242	−2.75513	0.48891	−2.01166	0.61784	−2.7017	0.72854	−2.90274	0.85485	−2.77389	0.98215	−2.04386
0.06003	−2.40921	0.17537	−2.8451	0.36484	−2.74177	0.49133	−1.98877	0.62027	−2.70658	0.73066	−2.90888	0.8573	−2.7617	0.98702	−1.98281
0.06245	−2.42447	0.17779	−2.85051	0.36729	−2.73862	0.49378	−1.97986	0.62269	−2.69653	0.7328	−2.90865	0.85975	−2.76831	0.98945	−1.9633
0.06489	−2.44209	0.18024	−2.84424	0.36971	−2.72806	0.4962	−1.96517	0.62513	−2.71518	0.73492	−2.91122	0.86219	−2.75583	0.99189	−1.9259
0.06732	−2.46367	0.18266	−2.84663	0.37214	−2.73617	0.49863	−1.95302	0.62756	−2.72997	0.73704	−2.91355	0.86465	−2.74583	0.99432	−1.91192
0.06976	−2.47867	0.18509	−2.85931	0.37458	−2.70993	0.50107	−1.94665	0.63	−2.74165	0.73917	−2.91012	0.86709	−2.73278	0.99676	−1.90174
0.07219	−2.49466	0.18753	−2.86587	0.37701	−2.71376	0.5035	−1.95985	0.63243	−2.73494	0.74224	−2.91808	0.86773	−2.73114	0.99919	−1.88677
0.07463	−2.51074	0.18996	−2.86892	0.37945	−2.70755	0.50594	−1.97323	0.63486	−2.7401	0.7447	−2.90535	0.87015	−2.72807		
0.07706	−2.50941	0.1924	−2.87628	0.38188	−2.69886	0.50837	−1.98906	0.6373	−2.75148	0.74714	−2.91633	0.87259	−2.71877		
0.07949	−2.53364	0.19483	−2.87465	0.38431	−2.69415	0.51079	−2.01354	0.63973	−2.7619	0.74958	−2.91838	0.87502	−2.71053		
0.08193	−2.53629	0.19726	−2.88316	0.38675	−2.68717	0.51324	−2.02907	0.64215	−2.76213	0.75204	−2.9182	0.87995	−2.68977		
0.08436	−2.56227	0.1997	−2.88443	0.38917	−2.67088	0.51566	−2.04714	0.64459	−2.77119	0.75448	−2.91441	0.88239	−2.69408		
0.0868	−2.56658	0.20212	−2.88243	0.3916	−2.66103	0.51809	−2.07991	0.64702	−2.77799	0.75693	−2.90231	0.88482	−2.67279		
0.08922	−2.57438	0.20457	−2.8838	0.39404	−2.65032	0.52053	−2.10923	0.64945	−2.789	0.75938	−2.91255	0.88726	−2.66112		
0.09167	−2.59097	0.20699	−2.89142	0.39647	−2.64854	0.52296	−2.12881	0.65189	−2.78569	0.76183	−2.91674	0.88969	−2.66222		
0.09409	−2.60145	0.20944	−2.88707	0.3989	−2.62981	0.52539	−2.15151	0.65432	−2.79264	0.76427	−2.91543	0.89211	−2.6606		
0.09652	−2.60254	0.21186	−2.90042	0.40134	−2.63292	0.52783	−2.16762	0.65676	−2.79317	0.76673	−2.91742	0.89456	−2.6489		
0.09896	−2.61884	0.21429	−2.89662	0.40377	−2.61108	0.53026	−2.19838	0.65919	−2.8015	0.76917	−2.90695	0.89698	−2.63598		
0.10139	−2.6235	0.21673	−2.89962	0.40621	−2.60651	0.5327	−2.21399	0.66161	−2.80438	0.77161	−2.9075	0.89942	−2.62761		
0.10383	−2.63456	0.21916	−2.89488	0.40864	−2.59181	0.53512	−2.22909	0.66406	−2.81185	0.77407	−2.89946	0.90185	−2.61805		
0.09264	−2.58787	0.22159	−2.90558	0.41106	−2.58631	0.53755	−2.26353	0.66648	−2.80749	0.77651	−2.90237	0.90428	−2.60938		
0.09507	−2.59838	0.22403	−2.90302	0.4135	−2.58614	0.53999	−2.28376	0.66891	−2.81265	0.77897	−2.89794	0.90672	−2.59189		
0.09749	−2.60225	0.22647	−2.90597	0.41593	−2.56949	0.54242	−2.29165	0.64861	−2.77706	0.78141	−2.89785	0.90915	−2.58367		
0.09994	−2.62669	0.2289	−2.91003	0.41836	−2.54937	0.54485	−2.32407	0.66167	−2.81517	0.78387	−2.90037	0.91159	−2.56775		
0.10236	−2.63003	0.23132	−2.90548	0.4208	−2.53526	0.54729	−2.34494	0.66372	−2.80812	0.78631	−2.89349	0.91402	−2.5695		
0.10481	−2.64804	0.23377	−2.91285	0.42323	−2.53884	0.54972	−2.36949	0.66575	−2.82567	0.78875	−2.89574	0.91646	−2.54958		
0.10723	−2.65323	0.23619	−2.90505	0.42565	−2.52221	0.55459	−2.39152	0.66778	−2.81809	0.79121	−2.89547	0.91889	−2.53503		
0.1121	−2.66424	0.23862	−2.9147	0.4281	−2.49961	0.55701	−2.40518	0.67048	−2.83263	0.79365	−2.89151	0.92131	−2.53146		
0.11453	−2.67658	0.24106	−2.90452	0.43052	−2.47183	0.55945	−2.42435	0.67324	−2.83427	0.79611	−2.89096	0.92375	−2.50639		

Table A.2 New Data on BH Cen in the B Band

Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm
0.00229	−0.42041	0.11521	−1.19781	0.24415	−1.42475	0.4458	−0.8949	0.57471	−1.03103	0.68868	−1.36152	0.81146	−1.37684	0.94145	−0.91863
0.00472	−0.44145	0.11764	−1.1986	0.2466	−1.419	0.44822	−0.88086	0.57715	−1.03828	0.69082	−1.37469	0.81391	−1.37395	0.94388	−0.9078
0.00716	−0.46071	0.12006	−1.20662	0.24902	−1.41689	0.45065	−0.87263	0.57958	−1.04857	0.69294	−1.37486	0.81636	−1.36466	0.94632	−0.88776
0.00959	−0.48805	0.1225	−1.21517	0.25146	−1.42176	0.45309	−0.85	0.58201	−1.06346	0.69507	−1.38125	0.8188	−1.3582	0.94875	−0.86853
0.01202	−0.51335	0.12493	−1.21889	0.25389	−1.42031	0.45552	−0.83003	0.58445	−1.07555	0.69719	−1.38099	0.82125	−1.35371	0.95119	−0.84704
0.01446	−0.52939	0.12737	−1.23283	0.25632	−1.41957	0.45795	−0.81236	0.58688	−1.0836	0.69933	−1.38522	0.8237	−1.34923	0.95362	−0.83582
0.01689	−0.55645	0.1298	−1.23489	0.25876	−1.41904	0.46039	−0.787	0.5893	−1.09602	0.70145	−1.38042	0.82614	−1.34702	0.95605	−0.81265
0.01933	−0.58163	0.13223	−1.24149	0.26363	−1.4183	0.46281	−0.76475	0.59175	−1.11244	0.70357	−1.39165	0.8286	−1.34264	0.95849	−0.79064
0.02175	−0.61076	0.13467	−1.24723	0.26606	−1.41716	0.46526	−0.75553	0.59417	−1.11829	0.7057	−1.393	0.83104	−1.33272	0.96091	−0.77349
0.0242	−0.6319	0.1371	−1.25982	0.26848	−1.41892	0.46768	−0.72833	0.59661	−1.13114	0.70782	−1.38968	0.83348	−1.33166	0.96336	−0.75163
0.02662	−0.66082	0.13954	−1.26629	0.27335	−1.41503	0.47011	−0.70944	0.59904	−1.14196	0.71208	−1.39679	0.83594	−1.32635	0.96578	−0.73522
0.02906	−0.68106	0.14197	−1.26618	0.34362	−1.30542	0.47255	−0.69026	0.60147	−1.15053	0.71421	−1.39806	0.83838	−1.32142	0.97065	−0.68912
0.03149	−0.70035	0.14441	−1.28277	0.34606	−1.298	0.47498	−0.66492	0.60391	−1.15548	0.71633	−1.39874	0.84084	−1.31518	0.97308	−0.66322
0.03392	−0.72187	0.14683	−1.28105	0.34849	−1.29194	0.47741	−0.64937	0.60634	−1.16622	0.71847	−1.40604	0.84328	−1.3097	0.97552	−0.63937
0.03636	−0.74678	0.14926	−1.29178	0.35092	−1.28771	0.47985	−0.62466	0.60877	−1.17389	0.72059	−1.40868	0.84574	−1.30618	0.97795	−0.61057
0.03879	−0.76527	0.1517	−1.29735	0.35336	−1.28581	0.48228	−0.60008	0.61121	−1.1777	0.72271	−1.39958	0.84818	−1.29983	0.98039	−0.58839
0.04123	−0.79119	0.15413	−1.3048	0.35579	−1.27936	0.4847	−0.58123	0.61363	−1.19046	0.72484	−1.40533	0.85062	−1.29504	0.98282	−0.56595
0.04366	−0.80817	0.15657	−1.30822	0.35821	−1.27074	0.48714	−0.55144	0.61608	−1.18954	0.72696	−1.41461	0.85308	−1.28569	0.98526	−0.53374
0.0461	−0.82878	0.159	−1.31539	0.36066	−1.26368	0.48957	−0.5289	0.6185	−1.20416	0.7291	−1.41011	0.85552	−1.2796	0.98769	−0.51298
0.04853	−0.8507	0.16143	−1.3227	0.36308	−1.25862	0.49201	−0.50983	0.62093	−1.21205	0.73122	−1.41773	0.85798	−1.27906	0.99013	−0.48532
0.05095	−0.86206	0.16387	−1.32864	0.36551	−1.25042	0.49444	−0.4918	0.62337	−1.21104	0.73335	−1.42093	0.86042	−1.27067	0.99256	−0.46786
0.05339	−0.88818	0.1663	−1.33205	0.36795	−1.24162	0.49687	−0.47663	0.6258	−1.22663	0.73547	−1.41088	0.86287	−1.26309	0.99498	−0.44748
0.05582	−0.90412	0.16874	−1.33363	0.37282	−1.23058	0.49931	−0.46972	0.62823	−1.22907	0.73761	−1.42066	0.86532	−1.25542	0.99742	−0.43027
0.05826	−0.91807	0.17116	−1.34316	0.37525	−1.22393	0.50174	−0.47002	0.63067	−1.23231	0.73973	−1.41796	0.86776	−1.24473	0.99985	−0.41906
0.06069	−0.93327	0.17361	−1.34791	0.37767	−1.21346	0.50416	−0.47931	0.6331	−1.24078	0.74291	−1.42079	0.86839	−1.24084		
0.06313	−0.94917	0.17603	−1.34892	0.38012	−1.20745	0.50661	−0.49635	0.63554	−1.25083	0.74536	−1.41372	0.87083	−1.22942		
0.06556	−0.96369	0.17846	−1.35324	0.38254	−1.19945	0.50903	−0.51305	0.63796	−1.25032	0.7478	−1.42087	0.87326	−1.22884		
0.068	−0.98063	0.1809	−1.35948	0.38497	−1.19854	0.51147	−0.54363	0.64039	−1.27198	0.75026	−1.41696	0.87569	−1.21596		
0.07043	−0.99721	0.18333	−1.36298	0.38741	−1.18484	0.5139	−0.55955	0.64283	−1.26758	0.7527	−1.41981	0.88063	−1.20236		
0.07286	−1.00409	0.18577	−1.37231	0.38984	−1.18306	0.51633	−0.58087	0.64526	−1.27335	0.75516	−1.41717	0.88548	−1.18609		
0.0753	−1.02328	0.1882	−1.36744	0.39228	−1.16583	0.51877	−0.60796	0.64769	−1.27843	0.7576	−1.41784	0.88793	−1.18388		
0.07772	−1.03104	0.19063	−1.38306	0.39471	−1.16095	0.5212	−0.6227	0.65013	−1.28257	0.76004	−1.4205	0.89035	−1.17611		
0.08017	−1.04594	0.19307	−1.37656	0.39714	−1.15241	0.52363	−0.65731	0.65256	−1.28531	0.7625	−1.41963	0.89279	−1.16743		
0.08259	−1.06242	0.19549	−1.38473	0.39958	−1.14262	0.52607	−0.67453	0.65498	−1.29727	0.76494	−1.41897	0.89522	−1.15416		
0.08502	−1.07504	0.19794	−1.38593	0.402	−1.13303	0.52849	−0.69421	0.65743	−1.30108	0.7674	−1.41579	0.89765	−1.14949		
0.08746	−1.08361	0.20036	−1.38651	0.40443	−1.12803	0.53092	−0.71563	0.65985	−1.30351	0.76984	−1.41948	0.90009	−1.13597		
0.08989	−1.09386	0.2028	−1.393	0.40687	−1.12056	0.53336	−0.73837	0.66229	−1.30244	0.77229	−1.41442	0.90252	−1.12971		
0.09233	−1.10724	0.20523	−1.39583	0.4093	−1.11149	0.53579	−0.75344	0.66472	−1.31809	0.77474	−1.41211	0.90496	−1.11755		
0.09476	−1.1159	0.20766	−1.39912	0.41173	−1.09542	0.53823	−0.78395	0.66715	−1.32194	0.77719	−1.40784	0.90739	−1.11149		
0.0972	−1.12229	0.2101	−1.39853	0.41417	−1.08566	0.54066	−0.8034	0.66959	−1.33432	0.77963	−1.40803	0.90983	−1.09724		
0.09963	−1.13638	0.21253	−1.41022	0.4166	−1.0646	0.54309	−0.81993	0.64927	−1.2985	0.78208	−1.40496	0.91225	−1.08626		
0.10207	−1.14447	0.21496	−1.40662	0.41904	−1.06167	0.54553	−0.83704	0.66217	−1.31525	0.78453	−1.40013	0.91468	−1.07361		
0.1045	−1.156	0.2174	−1.40912	0.42147	−1.0502	0.54796	−0.85997	0.66422	−1.32132	0.78697	−1.40022	0.91712	−1.06249		
0.09331	−1.10508	0.21982	−1.40769	0.42389	−1.03505	0.55038	−0.87443	0.66625	−1.31999	0.78943	−1.39789	0.91955	−1.04661		
0.09573	−1.1158	0.22469	−1.4159	0.42633	−1.02423	0.55282	−0.88857	0.6683	−1.33209	0.79187	−1.39664	0.92199	−1.03571		
0.09817	−1.12374	0.22713	−1.41633	0.42876	−1.00815	0.55525	−0.90578	0.67103	−1.34154	0.79433	−1.39269	0.92442	−1.0231		
0.1006	−1.13814	0.22956	−1.41501	0.43119	−0.99007	0.55769	−0.92739	0.6738	−1.34349	0.79677	−1.39001	0.92685	−1.01385		
0.10303	−1.14479	0.23199	−1.41739	0.43363	−0.98318	0.56012	−0.93975	0.67805	−1.34767	0.79921	−1.38941	0.92929	−0.99361		
0.10547	−1.15396	0.23443	−1.42229	0.43606	−0.96976	0.56255	−0.95291	0.68019	−1.35479	0.80167	−1.3829	0.93172	−0.98445		
0.1079	−1.16836	0.23686	−1.41659	0.4385	−0.94787	0.56499	−0.96833	0.68231	−1.35434	0.80411	−1.38386	0.93416	−0.97599		
0.11034	−1.17516	0.2393	−1.41663	0.44093	−0.93206	0.56742	−0.98809	0.68443	−1.36081	0.80657	−1.3809	0.93658	−0.95987		
0.11277	−1.18313	0.24173	−1.42203	0.44335	−0.9218	0.57229	−1.01471	0.68656	−1.36336	0.80901	−1.37458	0.93903	−0.94245		

Table A.3 New Data on BH Cen in the V Band

Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm
0.00028	0.49037	0.11318	−0.26355	0.23972	−0.49238	0.43162	−0.08196	0.56054	−0.02694	0.67416	−0.41876	0.7923	−0.47681	0.91997	−0.13537
0.00271	0.48361	0.11562	−0.27202	0.24214	−0.49402	0.43405	−0.05919	0.56298	−0.05748	0.6763	−0.42478	0.79475	−0.4678	0.92241	−0.12516
0.00514	0.46651	0.11805	−0.28359	0.24459	−0.49547	0.43647	−0.0469	0.56541	−0.0667	0.67842	−0.43025	0.79719	−0.46748	0.92484	−0.10525
0.00758	0.44849	0.12049	−0.2912	0.24701	−0.49907	0.43892	−0.04444	0.56783	−0.06908	0.68055	−0.4394	0.79965	−0.46316	0.92728	−0.10286
0.01001	0.42145	0.12292	−0.29742	0.24944	−0.49652	0.44134	−0.02296	0.57027	−0.08849	0.68267	−0.43734	0.80209	−0.46713	0.92971	−0.07749
0.01245	0.39894	0.12535	−0.30902	0.25188	−0.49907	0.44377	−0.00547	0.5727	−0.10355	0.68481	−0.44611	0.80455	−0.45909	0.93213	−0.06564
0.01487	0.36817	0.12779	−0.31237	0.25431	−0.49909	0.44621	0.00581	0.57513	−0.11968	0.68693	−0.44455	0.80699	−0.45388	0.93457	−0.0443
0.01732	0.35099	0.13022	−0.32506	0.25675	−0.49681	0.44864	0.04158	0.57757	−0.12702	0.68906	−0.44539	0.80943	−0.44873	0.937	−0.03392
0.01974	0.32089	0.13266	−0.32428	0.25918	−0.50143	0.45108	0.05167	0.58	−0.1418	0.69118	−0.45173	0.81189	−0.44579	0.93944	−0.01989
0.02217	0.29613	0.13509	−0.32907	0.2616	−0.49263	0.45351	0.05893	0.58244	−0.15569	0.6933	−0.45771	0.81433	−0.44681	0.94187	−0.00535
0.02461	0.27276	0.13753	−0.34017	0.26405	−0.49744	0.45594	0.07128	0.58487	−0.16697	0.69544	−0.46156	0.81679	−0.44534	0.94431	0.01105
0.02704	0.24672	0.13995	−0.34276	0.26647	−0.48738	0.45838	0.1014	0.58729	−0.17553	0.69756	−0.46001	0.81923	−0.4361	0.94674	0.02848
0.02948	0.22768	0.14238	−0.35505	0.26892	−0.49812	0.46323	0.14049	0.58974	−0.1903	0.69969	−0.46954	0.82169	−0.42943	0.94917	0.05054
0.03191	0.20485	0.14482	−0.37085	0.27134	−0.48996	0.46567	0.15099	0.59216	−0.20015	0.70181	−0.46314	0.82413	−0.43037	0.95161	0.06666
0.03435	0.18156	0.14725	−0.36323	0.27377	−0.49142	0.4681	0.18369	0.59459	−0.20901	0.70395	−0.46737	0.82657	−0.42194	0.95404	0.08521
0.03678	0.16249	0.14969	−0.36922	0.27621	−0.48784	0.47053	0.19682	0.59703	−0.20947	0.70607	−0.47067	0.82903	−0.41495	0.95648	0.1032
0.03922	0.1383	0.15212	−0.37976	0.34404	−0.39708	0.47297	0.23187	0.59946	−0.22696	0.7082	−0.47509	0.83147	−0.41965	0.9589	0.12252
0.04165	0.11446	0.15455	−0.383	0.34648	−0.38173	0.4754	0.24876	0.6019	−0.2328	0.71032	−0.47935	0.83392	−0.40923	0.96135	0.14254
0.04407	0.10447	0.15699	−0.39189	0.34891	−0.37702	0.47784	0.27204	0.60433	−0.25771	0.71246	−0.48165	0.83637	−0.40448	0.96377	0.16707
0.04652	0.08185	0.15942	−0.40103	0.35133	−0.37064	0.48027	0.29503	0.60675	−0.25204	0.71458	−0.48074	0.83882	−0.39716	0.9662	0.18452
0.04894	0.06279	0.16186	−0.39776	0.35378	−0.36734	0.48269	0.31425	0.6092	−0.26295	0.7167	−0.48798	0.84126	−0.39237	0.96864	0.20717
0.05138	0.04708	0.16428	−0.40182	0.3562	−0.36731	0.48513	0.34071	0.61162	−0.27335	0.71883	−0.48515	0.8437	−0.38676	0.97107	0.23125
0.05381	0.02465	0.16673	−0.41086	0.35865	−0.35653	0.48756	0.35971	0.61405	−0.28106	0.72095	−0.48062	0.84616	−0.38158	0.97351	0.25141
0.05625	0.01179	0.16915	−0.42032	0.36107	−0.34701	0.48999	0.38397	0.61649	−0.287	0.72309	−0.47781	0.8486	−0.37753	0.97594	0.27732
0.05868	−0.01278	0.17158	−0.41682	0.3635	−0.34655	0.49243	0.41077	0.61892	−0.2938	0.72521	−0.48927	0.85106	−0.36692	0.97838	0.30347
0.06111	−0.02472	0.17402	−0.42987	0.36594	−0.33785	0.49486	0.42925	0.62136	−0.30063	0.72734	−0.48494	0.8535	−0.36209	0.98081	0.32402
0.06355	−0.04326	0.17645	−0.42955	0.36837	−0.33643	0.4973	0.44164	0.62379	−0.3073	0.72946	−0.49106	0.85596	−0.35903	0.98323	0.35256
0.06598	−0.05458	0.17889	−0.43739	0.3708	−0.32283	0.49973	0.44708	0.62622	−0.31101	0.7316	−0.49227	0.8584	−0.35421	0.98568	0.37454
0.06842	−0.07259	0.18132	−0.43596	0.37324	−0.31428	0.50215	0.44687	0.62866	−0.33165	0.73372	−0.48496	0.86084	−0.3446	0.9881	0.40021
0.07085	−0.08823	0.18375	−0.44309	0.37566	−0.30788	0.5046	0.43368	0.63108	−0.33381	0.73584	−0.4923	0.8633	−0.34468	0.99054	0.42474
0.07329	−0.09136	0.18619	−0.45337	0.37811	−0.30035	0.50702	0.41138	0.63351	−0.33299	0.73797	−0.49392	0.86574	−0.33535	0.99297	0.44942
0.07571	−0.11288	0.18861	−0.45451	0.38053	−0.30055	0.50945	0.3951	0.63595	−0.34345	0.74009	−0.49174	0.8682	−0.32687	0.99541	0.45938
0.07814	−0.12409	0.19106	−0.45415	0.38296	−0.29045	0.51189	0.37382	0.63838	−0.35712	0.74334	−0.49195	0.86881	−0.32605	0.99784	0.47774
0.08058	−0.13596	0.19348	−0.45658	0.3854	−0.28347	0.51432	0.34552	0.64082	−0.3587	0.74579	−0.49396	0.87125	−0.3225		
0.08301	−0.14604	0.19593	−0.47112	0.38783	−0.2777	0.51676	0.3162	0.64325	−0.35943	0.74824	−0.4965	0.87368	−0.31505		
0.08545	−0.17119	0.19835	−0.46411	0.39026	−0.25915	0.51919	0.30666	0.64568	−0.36553	0.75068	−0.49972	0.87612	−0.30532		
0.08788	−0.17307	0.20078	−0.46503	0.3927	−0.25385	0.52161	0.26852	0.64812	−0.37118	0.75313	−0.48948	0.88105	−0.29326		
0.09032	−0.18487	0.20322	−0.47164	0.39513	−0.2475	0.52406	0.25905	0.65055	−0.37589	0.75558	−0.49525	0.88347	−0.28823		
0.09275	−0.19294	0.20565	−0.46692	0.39757	−0.23525	0.52648	0.23342	0.65297	−0.38584	0.75802	−0.49545	0.88591	−0.27344		
0.09518	−0.20145	0.20809	−0.47581	0.39999	−0.23104	0.52891	0.21726	0.65541	−0.3915	0.76048	−0.50057	0.88834	−0.26593		
0.09762	−0.21812	0.21052	−0.47618	0.40242	−0.21425	0.53135	0.18851	0.65784	−0.39769	0.76292	−0.49166	0.89077	−0.26166		
0.10004	−0.22196	0.21294	−0.48319	0.40486	−0.21636	0.53378	0.16644	0.66027	−0.40702	0.76538	−0.49316	0.89321	−0.25203		
0.10249	−0.23074	0.21539	−0.48024	0.40729	−0.20711	0.53621	0.14917	0.66271	−0.40395	0.76782	−0.49671	0.89564	−0.23964		
0.10491	−0.24803	0.21781	−0.48019	0.40972	−0.18945	0.53865	0.12578	0.66514	−0.41143	0.77026	−0.48822	0.89808	−0.23265		
0.09372	−0.19995	0.22026	−0.48759	0.41216	−0.17928	0.54108	0.10542	0.66758	−0.4184	0.77272	−0.48955	0.90051	−0.21936		
0.09615	−0.20411	0.22268	−0.48886	0.41459	−0.17171	0.54352	0.09108	0.67001	−0.41827	0.77516	−0.4864	0.90295	−0.21686		
0.09859	−0.20873	0.22512	−0.49348	0.41701	−0.15957	0.54594	0.07427	0.64969	−0.37827	0.77762	−0.48384	0.90538	−0.20384		
0.10102	−0.2259	0.22755	−0.48485	0.41946	−0.14062	0.54837	0.05012	0.66253	−0.41215	0.78006	−0.48875	0.9078	−0.19574		
0.10346	−0.2314	0.22998	−0.49123	0.42188	−0.13559	0.55081	0.02724	0.66456	−0.40209	0.78251	−0.48653	0.91024	−0.17986		
0.10589	−0.23657	0.23242	−0.49106	0.42432	−0.11669	0.55324	0.02532	0.6666	−0.41113	0.78496	−0.47951	0.91267	−0.17254		
0.10833	−0.25204	0.23485	−0.49812	0.42675	−0.11156	0.55567	−0.00403	0.66864	−0.42452	0.78741	−0.48065	0.91511	−0.15918		
0.11076	−0.2556	0.23727	−0.49401	0.42918	−0.10025	0.55811	−0.01227	0.6714	−0.41989	0.78985	−0.47472	0.91754	−0.14745		

Table A.4 New Data on BH Cen in the R Band

Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm
0.00063	1.02474	0.11355	0.25816	0.24007	0.03987	0.43197	0.4482	0.56089	0.50385	0.67662	0.08828	0.79511	0.06301	0.92763	0.43734
0.00306	1.00817	0.11598	0.25069	0.24249	0.04117	0.4344	0.47681	0.56333	0.47892	0.67875	0.09112	0.79757	0.06384	0.93006	0.45034
0.0055	0.98799	0.1184	0.24689	0.24494	0.04094	0.43684	0.49227	0.56576	0.45884	0.68087	0.09036	0.80001	0.06331	0.9325	0.46594
0.00793	0.97318	0.12084	0.23522	0.24736	0.03542	0.43927	0.50561	0.5682	0.46392	0.68301	0.09201	0.80245	0.07881	0.93493	0.48007
0.01037	0.94236	0.12327	0.22787	0.24981	0.03836	0.44169	0.51042	0.57063	0.44226	0.68513	0.08583	0.80491	0.0797	0.93737	0.49915
0.0128	0.92291	0.12571	0.22196	0.25223	0.03819	0.44414	0.54796	0.57305	0.43133	0.68725	0.08462	0.80735	0.08088	0.93979	0.51612
0.01524	0.89918	0.12814	0.21415	0.25466	0.03644	0.44656	0.54029	0.57549	0.41958	0.68938	0.08535	0.80981	0.08741	0.94222	0.53386
0.01767	0.86657	0.13058	0.20601	0.2571	0.04282	0.44899	0.55663	0.57792	0.4019	0.6915	0.08508	0.81225	0.08942	0.94466	0.54154
0.02009	0.84841	0.13301	0.20054	0.25953	0.04543	0.45143	0.59093	0.58035	0.39198	0.69364	0.07508	0.8147	0.09101	0.94709	0.55986
0.02254	0.82231	0.13544	0.20673	0.26197	0.03304	0.45386	0.6043	0.58279	0.37472	0.69576	0.07848	0.81715	0.10021	0.94953	0.5845
0.02496	0.80324	0.13788	0.19173	0.2644	0.04251	0.45873	0.64688	0.58522	0.36987	0.69789	0.07337	0.82204	0.09754	0.95196	0.60495
0.02741	0.78111	0.14031	0.1821	0.26682	0.04357	0.46116	0.65236	0.58766	0.35204	0.70001	0.06655	0.82449	0.10795	0.9544	0.61668
0.02983	0.75729	0.14275	0.17937	0.26927	0.04896	0.4636	0.66691	0.59009	0.3389	0.70215	0.06895	0.82694	0.11262	0.95683	0.6301
0.03227	0.73392	0.14517	0.17896	0.27169	0.04711	0.46602	0.70186	0.59251	0.33603	0.70427	0.06739	0.82938	0.12133	0.95926	0.65263
0.0347	0.70804	0.1476	0.16742	0.27413	0.04502	0.46845	0.72122	0.59496	0.32348	0.70639	0.0567	0.83184	0.11824	0.9617	0.67396
0.03713	0.68838	0.15004	0.15694	0.27656	0.04449	0.47089	0.7476	0.59738	0.30288	0.70852	0.05728	0.83428	0.12293	0.96412	0.69905
0.03957	0.67631	0.15247	0.15371	0.3444	0.14402	0.47332	0.76549	0.59981	0.30561	0.71064	0.06341	0.83672	0.13179	0.96657	0.71734
0.042	0.64833	0.15491	0.1448	0.34683	0.14923	0.47575	0.78497	0.60225	0.29804	0.71278	0.05367	0.83918	0.13474	0.96899	0.74554
0.04444	0.6292	0.15734	0.14289	0.34926	0.15597	0.47819	0.80938	0.60468	0.28954	0.7149	0.06119	0.84162	0.13722	0.97143	0.7598
0.04687	0.6116	0.15978	0.1364	0.3517	0.16492	0.48062	0.83598	0.60712	0.27311	0.71703	0.0566	0.84408	0.13936	0.97386	0.78867
0.04931	0.58795	0.16221	0.12592	0.35413	0.16708	0.48306	0.84725	0.60955	0.2727	0.71915	0.05247	0.84652	0.15331	0.97629	0.80665
0.05174	0.5793	0.16464	0.12527	0.35655	0.1773	0.48549	0.87512	0.61197	0.25782	0.72129	0.04404	0.84898	0.1557	0.97873	0.83935
0.05416	0.55304	0.16708	0.11918	0.359	0.18415	0.48791	0.89714	0.61442	0.26072	0.72341	0.04054	0.85142	0.16407	0.98116	0.86076
0.0566	0.53786	0.1695	0.1202	0.36142	0.18958	0.49035	0.92015	0.61684	0.24619	0.72553	0.04791	0.85386	0.16697	0.9836	0.88577
0.05903	0.523	0.17195	0.11652	0.36386	0.19744	0.49278	0.94106	0.61927	0.22626	0.72766	0.03389	0.85632	0.1723	0.98603	0.90552
0.06147	0.50781	0.17437	0.10338	0.36629	0.19899	0.49521	0.95757	0.62171	0.22539	0.72978	0.04168	0.85876	0.17397	0.98847	0.92912
0.0639	0.48723	0.1768	0.10111	0.36872	0.20287	0.49765	0.96904	0.62414	0.22773	0.73192	0.04225	0.86121	0.18804	0.9909	0.96031
0.06634	0.47301	0.17924	0.09868	0.37116	0.21491	0.50008	0.9665	0.62658	0.20659	0.73404	0.0554	0.86366	0.19599	0.99332	0.9812
0.06877	0.45854	0.18167	0.09247	0.37359	0.22625	0.5025	0.97193	0.62901	0.20666	0.73617	0.04406	0.8661	0.19765	0.99576	0.98967
0.0712	0.44202	0.18411	0.08979	0.37602	0.22406	0.50495	0.96399	0.63144	0.20185	0.73829	0.04454	0.86855	0.20763	0.99819	1.00839
0.07364	0.42738	0.18654	0.0842	0.37846	0.23365	0.50737	0.94296	0.63388	0.1976	0.74043	0.04857	0.86917	0.20862		
0.07606	0.42031	0.18898	0.0873	0.38088	0.24722	0.50982	0.92156	0.6363	0.19348	0.7437	0.03889	0.8716	0.22023		
0.07851	0.40396	0.19141	0.08106	0.38333	0.24603	0.51224	0.91034	0.63873	0.18103	0.74614	0.04141	0.87404	0.21736		
0.08093	0.39329	0.19383	0.08098	0.38575	0.261	0.51467	0.88114	0.64117	0.17685	0.7486	0.04291	0.8814	0.24482		
0.08338	0.38407	0.19628	0.08606	0.38818	0.27242	0.51711	0.85168	0.6436	0.17786	0.75104	0.03585	0.88382	0.2527		
0.0858	0.36592	0.1987	0.07135	0.39062	0.27677	0.51954	0.8372	0.64603	0.15475	0.7535	0.03664	0.88627	0.26353		
0.08823	0.35743	0.20115	0.07244	0.39305	0.28017	0.52197	0.8101	0.64847	0.16253	0.75594	0.03559	0.88869	0.26756		
0.09067	0.34522	0.20357	0.06518	0.39548	0.2863	0.52441	0.79119	0.6509	0.15968	0.7584	0.04423	0.89113	0.27375		
0.0931	0.33538	0.206	0.05958	0.39792	0.31181	0.52683	0.75476	0.65334	0.16518	0.76084	0.04418	0.89356	0.2867		
0.09554	0.3238	0.20844	0.05992	0.40035	0.30619	0.52928	0.74732	0.65577	0.1503	0.76328	0.03985	0.896	0.29335		
0.09797	0.32241	0.21087	0.05438	0.40279	0.31301	0.5317	0.71865	0.65819	0.14509	0.76574	0.04166	0.89843	0.3056		
0.10041	0.30235	0.21331	0.05579	0.40521	0.33495	0.53413	0.70026	0.66063	0.13354	0.76818	0.04259	0.90086	0.31576		
0.10284	0.30011	0.21574	0.05217	0.40764	0.33308	0.53657	0.67836	0.66306	0.12743	0.77064	0.04055	0.9033	0.32784		
0.10526	0.29041	0.21816	0.05174	0.41008	0.35105	0.539	0.66087	0.66549	0.12494	0.77308	0.04046	0.90573	0.33113		
0.09407	0.34292	0.22061	0.05174	0.41251	0.35669	0.54143	0.64151	0.66793	0.12402	0.77553	0.04972	0.90817	0.33581		
0.09651	0.32793	0.22303	0.05262	0.41494	0.36232	0.54387	0.62421	0.67036	0.11602	0.77797	0.05023	0.9106	0.35237		
0.09894	0.31995	0.22548	0.04915	0.41738	0.38486	0.5463	0.59802	0.66285	0.1298	0.78042	0.04616	0.91302	0.37006		
0.10138	0.31012	0.2279	0.04918	0.41981	0.39756	0.54874	0.57245	0.66489	0.13431	0.78287	0.05113	0.91546	0.36988		
0.10381	0.30145	0.23033	0.03612	0.42223	0.4039	0.55116	0.56537	0.66693	0.1184	0.78531	0.05678	0.91789	0.38337		
0.10625	0.28505	0.23277	0.04054	0.42468	0.41691	0.55359	0.54688	0.66897	0.1155	0.78777	0.05599	0.92033	0.395		
0.10868	0.27224	0.2352	0.03911	0.4271	0.4355	0.55603	0.53331	0.67174	0.11642	0.79021	0.06307	0.92276	0.40898		
0.11111	0.27734	0.23764	0.03902	0.42954	0.44485	0.55846	0.5168	0.6745	0.10042	0.79267	0.06834	0.9252	0.42702		

Table A.5 New Data on BH Cen in the I Band

Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm	Phase	Δm
0.00096	1.56913	0.11631	0.80034	0.24285	0.58862	0.44934	1.11339	0.57826	0.95062	0.68969	0.64854	0.82238	0.6685	0.9523	1.16074
0.0034	1.55632	0.11875	0.78484	0.24527	0.59548	0.45177	1.13165	0.5807	0.93773	0.69183	0.64941	0.82484	0.66859	0.95474	1.17523
0.00584	1.54261	0.12118	0.78156	0.2477	0.59702	0.4542	1.16009	0.58313	0.92718	0.69607	0.63598	0.82728	0.6752	0.95716	1.1971
0.00827	1.52332	0.12362	0.77871	0.25014	0.58756	0.45906	1.18726	0.58555	0.92084	0.6982	0.63033	0.82972	0.68793	0.95961	1.20934
0.01071	1.49392	0.12605	0.77082	0.25257	0.58727	0.46151	1.21954	0.588	0.91453	0.70032	0.63496	0.83218	0.68987	0.96203	1.23188
0.01313	1.46852	0.12848	0.76448	0.25501	0.5992	0.46393	1.23292	0.59042	0.89953	0.70246	0.63096	0.83462	0.69313	0.96446	1.25316
0.01558	1.44052	0.13092	0.75682	0.25744	0.59444	0.46636	1.25523	0.59286	0.88545	0.70458	0.63035	0.83707	0.69562	0.9669	1.27547
0.018	1.42491	0.13335	0.75187	0.26231	0.59835	0.4688	1.28114	0.59529	0.87891	0.70671	0.6287	0.83952	0.69717	0.97177	1.31551
0.02045	1.39396	0.13579	0.74127	0.27204	0.6026	0.47123	1.29464	0.59772	0.86621	0.70883	0.61964	0.84196	0.69748	0.9742	1.34124
0.02287	1.37668	0.13821	0.7287	0.34474	0.70721	0.47366	1.3113	0.60016	0.85462	0.71097	0.61764	0.84441	0.71724	0.97664	1.36499
0.0253	1.35092	0.14066	0.72722	0.34717	0.70688	0.4761	1.33298	0.60259	0.84474	0.71309	0.62764	0.84686	0.70753	0.97907	1.39021
0.02774	1.32549	0.14308	0.72928	0.34961	0.71097	0.47853	1.35904	0.60501	0.84116	0.71521	0.62339	0.84931	0.72516	0.98151	1.41185
0.03017	1.30485	0.14551	0.71151	0.35204	0.72133	0.48095	1.3774	0.60746	0.82858	0.71946	0.61659	0.85175	0.72208	0.98394	1.43724
0.03261	1.2826	0.14795	0.71425	0.35446	0.72392	0.48339	1.40561	0.60988	0.82302	0.7216	0.59918	0.85421	0.72122	0.98636	1.46594
0.03504	1.26049	0.15038	0.70365	0.35691	0.73324	0.48582	1.42905	0.61233	0.8121	0.72372	0.6196	0.85665	0.74369	0.9888	1.48931
0.03748	1.24306	0.15282	0.70044	0.35933	0.73753	0.48826	1.44216	0.61475	0.80663	0.72585	0.60366	0.85909	0.74011	0.99123	1.50911
0.03991	1.21703	0.15525	0.70445	0.36176	0.74461	0.49069	1.47067	0.61718	0.79968	0.72797	0.59837	0.86155	0.75391	0.99367	1.538
0.04233	1.19926	0.15768	0.6954	0.3642	0.74264	0.49312	1.48636	0.61962	0.79232	0.7301	0.60504	0.86399	0.76187	0.9961	1.54857
0.04478	1.17368	0.16012	0.68685	0.36663	0.7549	0.49556	1.51356	0.62205	0.78719	0.73222	0.60834	0.86645	0.76244	0.99854	1.56912
0.0472	1.16052	0.16254	0.67893	0.36907	0.76343	0.49799	1.52519	0.62448	0.7782	0.73436	0.61797	0.86889	0.76823		
0.04964	1.14211	0.16499	0.68183	0.3715	0.77118	0.50041	1.52979	0.62692	0.76223	0.73648	0.60438	0.86951	0.76634		
0.05451	1.11009	0.16741	0.67004	0.37392	0.77177	0.50286	1.52429	0.62934	0.76361	0.7386	0.6065	0.87194	0.7641		
0.05694	1.09759	0.16984	0.66316	0.37637	0.78481	0.50528	1.50529	0.63179	0.75755	0.74073	0.60929	0.87438	0.77932		
0.05938	1.0794	0.17228	0.65799	0.37879	0.78726	0.50772	1.49117	0.63421	0.74569	0.74404	0.61627	0.87681	0.78358		
0.06181	1.05674	0.17471	0.66021	0.38124	0.79692	0.51015	1.46816	0.63664	0.75564	0.7465	0.60693	0.88173	0.80059		
0.06424	1.04462	0.17715	0.65795	0.38366	0.80611	0.51258	1.44759	0.63908	0.73776	0.74894	0.60454	0.88417	0.80627		
0.06668	1.02988	0.17958	0.64752	0.38609	0.80371	0.51502	1.42382	0.64151	0.74111	0.75384	0.60287	0.8866	0.80864		
0.06911	1.0144	0.18202	0.64589	0.38853	0.81381	0.51745	1.39466	0.64394	0.71684	0.75628	0.60448	0.88904	0.82122		
0.07155	1.00067	0.18445	0.6435	0.39096	0.82735	0.51987	1.3745	0.64638	0.71833	0.75873	0.60418	0.89147	0.83648		
0.07397	0.98465	0.18687	0.63776	0.39339	0.83518	0.52232	1.35285	0.64881	0.72098	0.76607	0.61032	0.8939	0.83764		
0.07642	0.97656	0.18932	0.63736	0.39583	0.8532	0.52474	1.33257	0.65123	0.70627	0.76853	0.61257	0.89634	0.84998		
0.07884	0.96097	0.19174	0.63399	0.39825	0.85355	0.52717	1.30324	0.65367	0.69977	0.77097	0.61502	0.89877	0.86309		
0.08127	0.94908	0.19419	0.64063	0.40068	0.8608	0.52961	1.28933	0.6561	0.70283	0.77341	0.60888	0.90121	0.86548		
0.08371	0.9403	0.19661	0.62219	0.40312	0.86328	0.53204	1.2624	0.65854	0.70861	0.77587	0.60713	0.90364	0.8777		
0.08614	0.92942	0.19904	0.61891	0.40555	0.87193	0.53448	1.24348	0.66097	0.68823	0.77831	0.61247	0.90606	0.89449		
0.08858	0.91745	0.20148	0.6127	0.40798	0.89292	0.53691	1.22783	0.6634	0.69013	0.78077	0.61789	0.9085	0.89953		
0.09101	0.90086	0.20391	0.61393	0.41042	0.88969	0.53934	1.2086	0.66584	0.6749	0.78321	0.62492	0.91093	0.91759		
0.09345	0.89217	0.20635	0.61499	0.41285	0.91449	0.54178	1.18106	0.66827	0.67201	0.78567	0.61766	0.91337	0.91603		
0.09588	0.87969	0.20878	0.61272	0.41529	0.91464	0.5442	1.16689	0.67069	0.6752	0.78811	0.61755	0.9158	0.93119		
0.0983	0.87463	0.21122	0.60166	0.41772	0.93919	0.54663	1.15559	0.65039	0.72372	0.79056	0.62404	0.91824	0.94419		
0.10075	0.86662	0.21365	0.61465	0.42014	0.94319	0.54907	1.12882	0.66318	0.69641	0.79301	0.6219	0.92067	0.95987		
0.10317	0.84969	0.21607	0.59855	0.42258	0.95909	0.5515	1.11315	0.66522	0.69019	0.79545	0.63231	0.92554	0.9784		
0.10561	0.84704	0.21852	0.5944	0.42501	0.97114	0.55394	1.09752	0.66726	0.68842	0.7979	0.62987	0.92797	1.0001		
0.09442	0.88162	0.22094	0.59413	0.42744	0.98093	0.55637	1.08484	0.6693	0.67669	0.80035	0.63813	0.93041	1.00827		
0.09685	0.87334	0.22337	0.59833	0.42988	0.99789	0.5588	1.07118	0.67207	0.67099	0.8028	0.63345	0.93283	1.02058		
0.09928	0.85842	0.22581	0.60424	0.43231	1.0007	0.56124	1.04301	0.67481	0.67124	0.80524	0.6408	0.93526	1.04362		
0.10172	0.85553	0.22825	0.60021	0.43475	1.02749	0.56367	1.03965	0.67693	0.66801	0.8077	0.64408	0.9377	1.05273		
0.10415	0.84633	0.23068	0.60335	0.43718	1.02644	0.56609	1.01818	0.67906	0.66175	0.81014	0.64999	0.94013	1.06383		
0.10659	0.83511	0.23311	0.59303	0.4396	1.06305	0.56853	1.00358	0.68118	0.65471	0.81258	0.64905	0.94257	1.0929		
0.10902	0.82862	0.23555	0.59043	0.44205	1.06711	0.57096	0.99262	0.68332	0.66266	0.81504	0.65297	0.945	1.10408		
0.11146	0.81143	0.23798	0.59763	0.44447	1.08853	0.5734	0.98153	0.68544	0.64614	0.81748	0.66287	0.94744	1.11482		
0.11388	0.81156	0.2404	0.59152	0.4469	1.08694	0.57583	0.96377	0.68757	0.65055	0.81994	0.66333	0.94987	1.13705		