The Contact System V566 Ophiuchi Revisited

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Abstract. New CCD photometric observations of the eclipsing binary V566 Oph have been obtained. The light curves are analyzed with the Wilson-Devinney code and new geometric and photometric elements are derived. A new O-C analysis of the system is presented and apparent period changes are discussed with respect to possible Light-Time Effect in the system.

1. Introduction

The aim of the present study is the investigation for a possible qualitative connection between the solutions derived from the light curve and O-C diagram analysis of the system. The presence of possible tertiary components orbiting the eclipsing binary (hereafter EB) and the mass transfer process are mechanisms which can affect both the period of the EB and the shape and brightness levels of the light curves (hereafter LCs). These two independent methods of analysis (light curve and O-C diagram analysis) are applied in the present study and combined with the results from previous spectroscopic ones in order to get a better and more clear picture of the system.

The system V566 Oph (= HIP 87860 = HD 163611, $\alpha_{2000} = 17^h56^m52.4^s$, $\delta_{2000} = +04°59'15.3''$) is a W UMa - type eclipsing binary, discovered by Hoffmeister (1935). The system has been observed photometrically and spectroscopically by many researchers in the past (for references see D (2006)). The distance of the system has been determined by HIPPARCOS mission to be 71.531 pc (Perryman 1997). Pribulla & Rucinski (2006) carried out a period study of the system and calculated the physical and orbital elements of a possible third body orbiting the EB. Later, Patsis (2006) published the most recent spectroscopic mass ratio of the system using the broadening function (BF) method and the rotational profile fitting. They also determined the spectral class of the system as F4V, and found no spectroscopic evidence of a tertiary component.

2. Observations and analysis

The system was observed during four nights in May 2009 at the Athens University Observatory, using a 40-cm Cassegrain telescope equipped with the CCD camera ST-8XMEI and the B, V, R, I Bessell photometric filters.

Differential magnitudes were obtained by using the software Muniwin v.1.1.23 (Hroch 1998), while the stars SAO 122955 and GSC 0425-1090 were selected as comparison and check stars, respectively. Two times of minima have been calculated using the Kwee & van Woerden (1956) method and are presented in Table 1.

Table 1.: The times of minima derived from our observations

HJD (2400000.0+)	$Error$	$Type$
54980.5158	0.0002	II
54982.3590	0.0005	I

2.1. Light curve analysis

The light curves (hereafter LCs) were analysed with the PHOEBE 0.29d software (Prša & Zwitter 2005) which uses the 2003 version of the Wilson-Devinney code (Wilson & Devinney 1971; Wilson 1979). Mode 3 was selected for the light curve analysis and the method of Multiple Subsets was used in order to obtain the final photometric solution. The value of the temperature T_1 of the primary component was adopted according to the spectral classification of Patsis (2006), and the mass ratio of the system was initially set at the spectroscopic value q_{sp}=0.263(12) (Patsis 2006), but during the final calculations it was adjusted with fixed step in order to be within the error limits of the q_{sp}. The albedos A_1, A_2 and the gravity darkening coefficients g_1, g_2 were given their theoretical values according to the spectral type of each component. The synthetic and observed LCs and the 3-D model of V566 Oph are shown in Fig. 1, while the derived parameters from the LC solution are listed in Table 2.

Table 2.: The parameters of V566 Oph derived from the LCs solution

$Parameter$	$value$	$Parameter$		$value$		
$q\ (m_2/m_1)$	0.252 (1)		B	V	R	I
i [deg]	80.7 (2)	$x_1{}^{**}$	0.625	0.510	0.429	0.351
$T_1{}^*$ [K]	6765	$x_2{}^{**}$	0.639	0.517	0.437	0.358
T_2 [K]	6650 (5)	L_1/L_T	0.757 (2)	0.766 (3)	0.769 (3)	0.770 (3)
$A_1{}^*=A_2{}^*$	0.5	L_2/L_T	0.207 (1)	0.213 (1)	0.216 (1)	0.219 (1)
$g_1{}^*=g_2{}^*$	0.32	L_3/L_T	0.036 (2)	0.021 (2)	0.015 (2)	0.012 (3)
$\Omega_1=\Omega_2$	2.295 (3)		$Pole$	$Side$	$Back$	
$Fillout Fact.$	36.7%	r_1	0.483	0.527	0.556	
χ^2	0.08404	r_2	0.264	0.277	0.326	

$^*assumed$,

***Van Hamme (1993)*, $L_T = L_1 + L_2 + L_3$

2.2. O-C diagram analysis

The least squares method with statistical weights has been used for the analysis of the O-C diagram. The weights assigned to individual observations were set at w=1 for visual observations, 5 for photographic and 10 for CCD and photoelectric observations. The current O-C diagram of V566 Oph includes 201 times of minima taken from the literature and two from our observations (see Table 1). The ephemeris: $Min\ I = HJD\ 2442911.23402+0.4096457^d \times E$ was used as the initial one for the O-C analysis of the compiled times of minima. Due to the distribution of the O-C points, one periodic
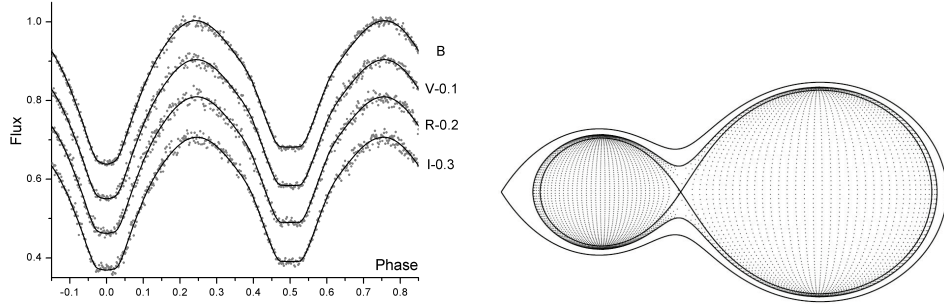
Figure 1.: Left panel: The synthetic LCs (solid lines) along with the observed ones (gray points). Right panel: The 3-D model of the system at the phase 0.75.

LITE (LIght Time Effect) curve (Frieboes-Conde & Herczeg 1973; Irwin 1959) and one parabola were chosen to fit the O-C diagram.

In Table 3 the derived parameters are presented, namely: the mass of each component of the EB, M_1 and M_2, respectively, the ephemeris ($Min.\ I$ and P for the linear one and c_2 for the quadratic one), the period change rate $\dot{P}$ and the mass transfer rate $\dot{M}$ of the EB, the period P_3, the minimal mass $M_{3,min}$ and the eccentricity e_3 of the third body, the HJD of the periastron passage T_0, the semi-amplitude A of the LITE, the argument of periastron ω, and the maximum angular separation α between the third body and the EB. The O-C solution is illustrated in Fig. 2.

Table 3.: The results of the O-C diagram analysis for V566 Oph

Parameters of the EB	*value*	*Parameters of the LITE and of the 3rd body*	*value*
$M_1^* + M_2$ $(M_\odot)$	1.4 + 0.35	P_3 [yrs]	62.3 (3)
$Min.I$ (HJD)	2442911.183 (5)	T_0 [HJD]	2408118 (1791)
P (days)	0.409646 (1)	ω [deg]	2 (14)
c_2 $(\times 10^{-10})$ $[days/cycle]$	1.457 (2)	A [days]	0.013 (3)
$\dot{P}$ $(\times 10^{-7})$ $[days/yr]$	2.598 (2)	e_3	0.6 (2)
$\dot{M}$ $(\times 10^{-8})$ $[M_\odot/yr]$	9.969 (8)	$M_{3,min}$ $[M_\odot]$	0.29 (5)
		α [mas]	279.7
χ^2	0.0521		

$^*assumed$

3.   Discussion and Conclusions

Complete new BVRI light curves were obtained for V566 Oph. The results of the LC solution show that V566 Oph is an overcontact system (fillout factor 36.7%) not in thermal equilibrium. An additional light contribution to the luminosity of the EB was taken into account in the LC solution and it was found 2.1%. The periodic variation of the orbital period of the system could be explained by adopting the existence of an additional component, which was found to have minimal mass of 0.29 $M_\odot$. Assuming that all members of the triple system are main sequence stars, we found that the luminosity from the third body, derived from the light curve analysis, could be produced by
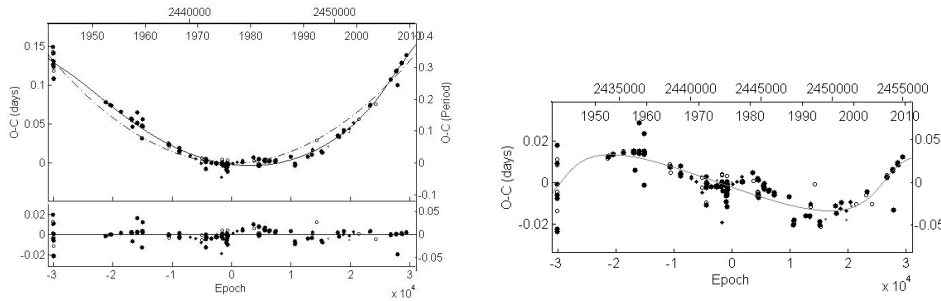
Figure 2.: Left panel: upper part: The total fit (solid line) on the O-C points (black points), the parabola (dashed line) and lower part: the O-C residuals. Right panel: The sinusoidal fit on the O-C points after the subtraction of the parabola.

a star with 0.47 $M_\odot$ and an orbital inclination of $i' = 41°$. Since such a body was not detected by the spectroscopic observations of Patsis (2006), the most probable explanation is that it is neither a main sequence star, nor does it contribute to the EB's period formation. The large angular separation, between the possible third body and the EB, allows further investigation of its existence by large interferometers. Moreover, the O-C residuals show another variation, not strictly periodic, which is possibly caused by another physical mechanism, such as magnetic activity, although its signature (O'Connell effect) was not observed in the LCs. The steady increase rate of its period is probably due to the mass transfer procedure whose direction of the flow is from the less massive to the more massive component.

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