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, based on the most reliable timings of minima found in the literature, is presented and apparent period changes are discussed with respect to possible Light-Time Effect (LITE) in the system. Moreover, the results concerning the existence of a tertiary component around the eclipsing pair, derived from the period study, are compared with those for extra luminosity, derived from the light curve analysis.

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 analysis) are apllied in the current 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, α_{2000} = 17^{h}56^{m}52.4^s, δ_{2000} = +04°59´15.3´´) is a W UMa - type eclipsing binary and was discovered by Hoffmeister (1935). The system has been observed photometrically and spectroscopically by many researchers (for references see Değirmenci 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, Pribulla et al. (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

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) and 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

3. Light curve analysis

The light curves were analysed with the *PHOEBE 0.29d* software (Prša & Zwitter 2005) which uses the 2003 version 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 of the primary component was adopted according to the spectral classification of Pribulla et al. (2006), and the mass ratio of the system was initially set as fixed value (q_{sp}=0.263(12), Pribulla et al. 2006), but during the final calculations it was adjusted, with fixed step of calculations in order to be to be within the error limits of the spectroscopic value. 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 light curves and the 3D model of V566 Oph are shown in Figs. 1 and 2, respectively, and the derived parameters from the light curve solution are listed in Table 2.

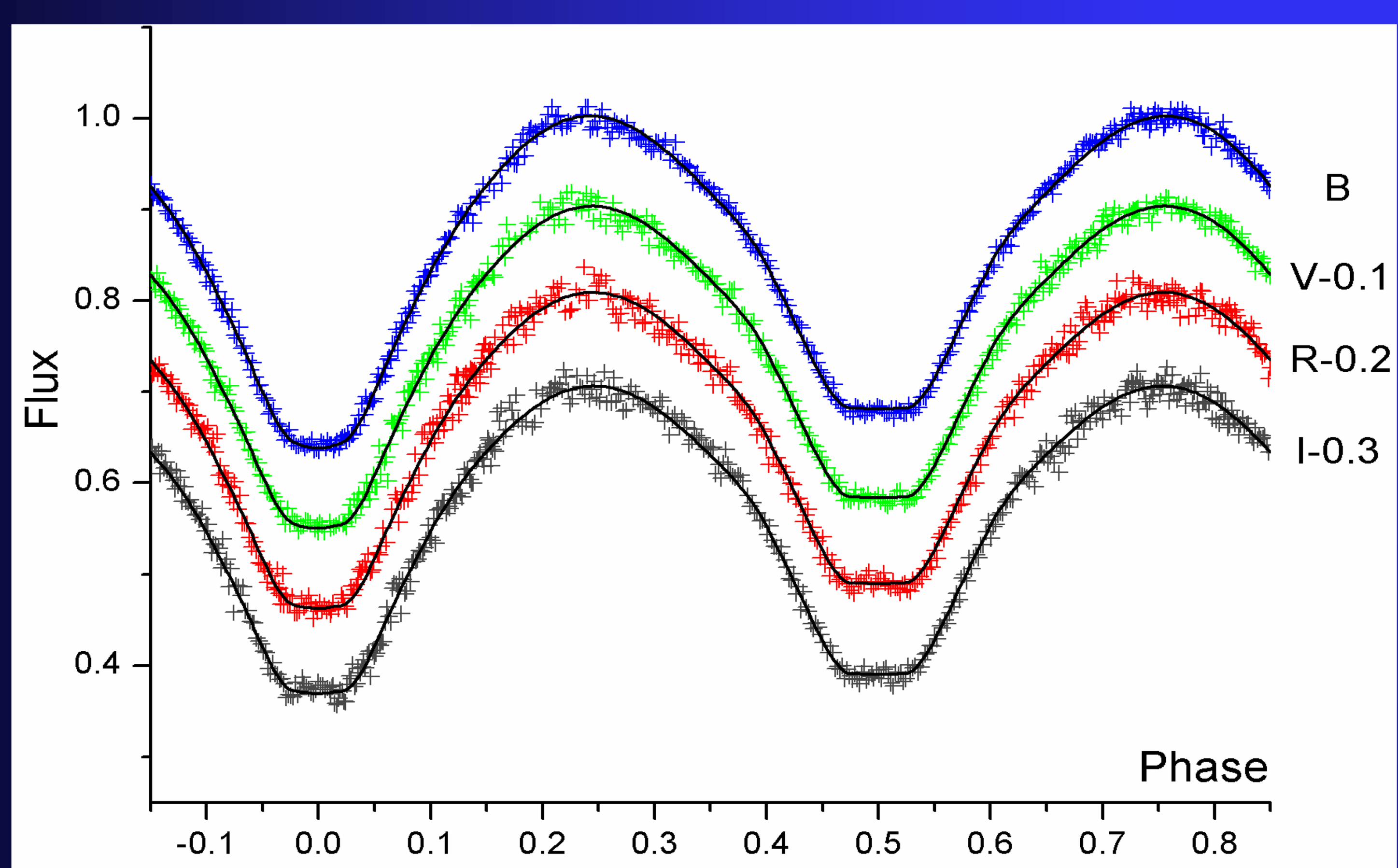


Fig. 1. The synthetic (solid lines) and the observed LCs (colored points) of V566 Oph in B, V, R, I filters.

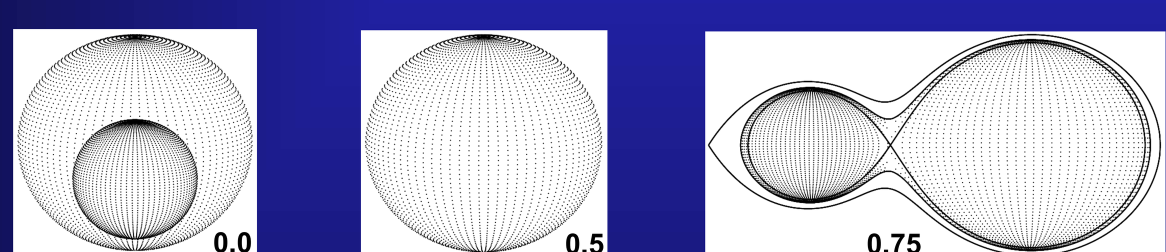


Fig. 2. The 3D model of V566 Oph in various phases.

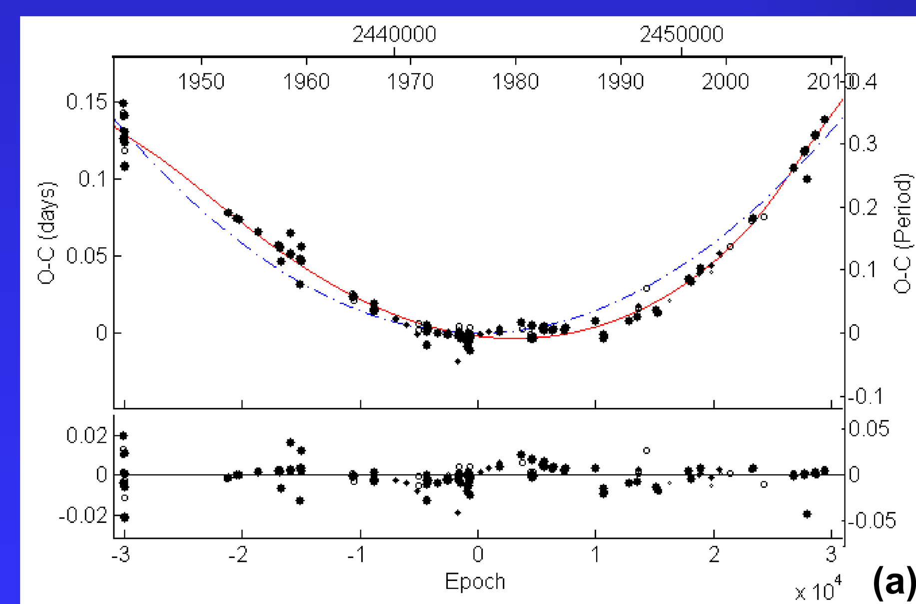
Table 2. The parameters of V566 Oph derived from the LC solution

Parameter	Value	Parameter	Value			
q	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, **taken from the tables of van Hamme (1993), $L_T = L_1 + L_2 + L_3$*

4. O-C diagram analysis

The least squares method 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 times of minima from our observations (see Table 1). The following ephemeris *Min.I = HJD 2442911.23402 + 0.40964569*^{d} × *E* was used to compute, initially, the O-C points of all compiled times of minima. Due to the distribution of the O-C points, one periodic LITE curve (Frieboes-Conde & Herczeg 1973; Irwin 1959) and one parabola were chosen to fit the O-C diagram. The final fit, the residuals of the analysis and the individual solution for the LITE are presented in Fig. 3, while the derived parameters are given in Table 3.



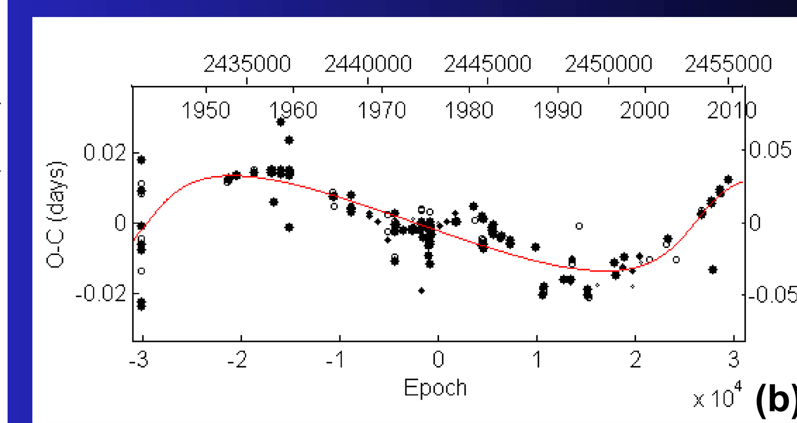


Fig. 3. (a-upper part) The O-C diagram of V566 Oph fitted by a periodic LITE curve and a parabola (dashed blue line). The combination of these functions constitutes the total solution (solid red line). (a-lower part) The O-C residuals after the subtraction of the total solution. (b) The O-C residuals after the subtraction of the parabola (Fig. 3a), fitted by the periodic term. The full circles represent the times of primary minima and the open circles those of the secondary minima; the bigger the symbol, the bigger the weight assigned.

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

Parameters of the EB	
M_1* + M_2 [$M_\odot$]	1.4 + 0.35
Min. I [HJD]	2442911.183 (5)
P [days]	0.409646 (1)
c_2 [days/cycle] (×10^{-10})	1.457 (2)
$\dot{P}$ [days/yr] (×10^{-7})	2.598 (2)
$\dot{M}$ [$M_\odot$/yr] (×10^{-8})	9.969 (8)
Parameters of the LITE	
P_3 [years]	62 (3)
T_0 ([HJD] (periastron passage)	2408118 (1791)
ω [deg] (periastron passage)	2 (14)
A [days] (semi-amplitude of O-C)	0.013 (3)
e (eccentricity)	0.6 (2)
α (angular separation) [mas]	279.7
f (m_3) [$M_\odot$]	0.006 (1)
$M_{3,min}$ (for i´=90°) [$M_\odot$]	0.29 (5)
χ^2	0.0521

**assumed*

5. Discussion and Conclusions

Complete new BVRI light curves were obtained for V566 Oph. The results of the light curve 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 stars of the triple system belong to the main sequence, we found that the luminosity from the third body, derived from the light curve analysis, could be produced by 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 Pribulla et al. (2006), the most probable explanation is that it is either not a main sequence star, or does not contribute to the EB's period formation. The large angular separation between the possible third body and the EB allows the large symbolometers to investigate its existence. Moreover, the O-C residuals probably 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.

6. Acknowledgements

This work has been financially supported by the Special Account for Research Grants No 70/4/9709 of the National & Kapodistrian University of Athens, Hellas. In the present work, the minima database: http://var.astro.cz/ocgate/ has been used. We thank P. Zasche for providing the Matlab code for computing the LITE elements.

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