The Algol type eclipsing binary X Tri: BVRI modelling and O-C diagram analysis

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Abstract

CCD photometric observations of the Algol-type eclipsing binary X Tri 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 and multiple Light-Time effect (LITE) in the system. Moreover, the results for the existence of additional bodies 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 the brightness levels of the light curves. These two independent methods of analysis (light curve and O-C analysis) will be combined in order to get a better and more clear picture of the system.

The system X Tri (=HIP 9383 = HD 12211 = SAO 75082, α_{2000} = $02^h00^m33.7^s$, δ_{2000} = +27°53´19.2´´) is an Algol-type eclipsing binary with an approximate period of 1 day and an apparent magnitude of V=9. The variable light behaviour of the system was discovered independently by Walker (1921) and Neujmin (1922). Giuricin et al. (1983) provided the most recent spectral classification of the components of the system as A3 and K0 respectively. The orbital period changes of the system have been studied by many authors most of whom assumed that the Light-Time Effect (Irwin 1959; Frieboes-Conde & Herczeg 1973), the mass transfer process and non-periodic mechanisms explain the O-C diagram. The distance of the system has been measured by the HIPPARCOS mission (Adelman 2001) as 165.84 pc.

2. Observations

The system was observed during 5 nights from October 2008 to January 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 stars SAO 75081 and GSC 1763-2015 as comparison and check stars, respectively. One time of primary minima has been calculated using the Kwee & van Woerden (1993) and resulted in HJD 2454764.39477(3).

3. Light curve analysis

The light curves were analysed with the PHOEBE 0.29d software (Prša and Zwitter 2005) which uses the 2003 version the Wilson-Devinney code (Wilson & Devinney 1971; Wilson 1979). Due to the lack of spectroscopic mass ratio of the system, the q-search method was applied in Mode 2 (detached system), 4 (semi-detached system with the primary component filling its Roche Lobe) and 5 (semi-detached system with the secondary component filling its Roche Lobe) in order to find the most probable value of the (photometric) mass ratio (q). In each Mode the method of Multiple Subsets was used in order to obtain the final photometric solutions. The values of the temperatures of the components were adopted according to the spectral classification of Giuricin et al. (1983) as A3 and K0, respectively. The minimum value of the weighted sum of the squared residuals was found in Mode 5. The q-search method in this mode converged to a mass ratio value close to 0.6. This value of q was used as initial value and then it was adjusted in the subsequent analysis in the same Mode. The synthetic and observed light curves and the 3D model of X Tri are shown in Figs.1 and 2, respectively, and the derived parameters from the light curve solution are listed in Table 1.

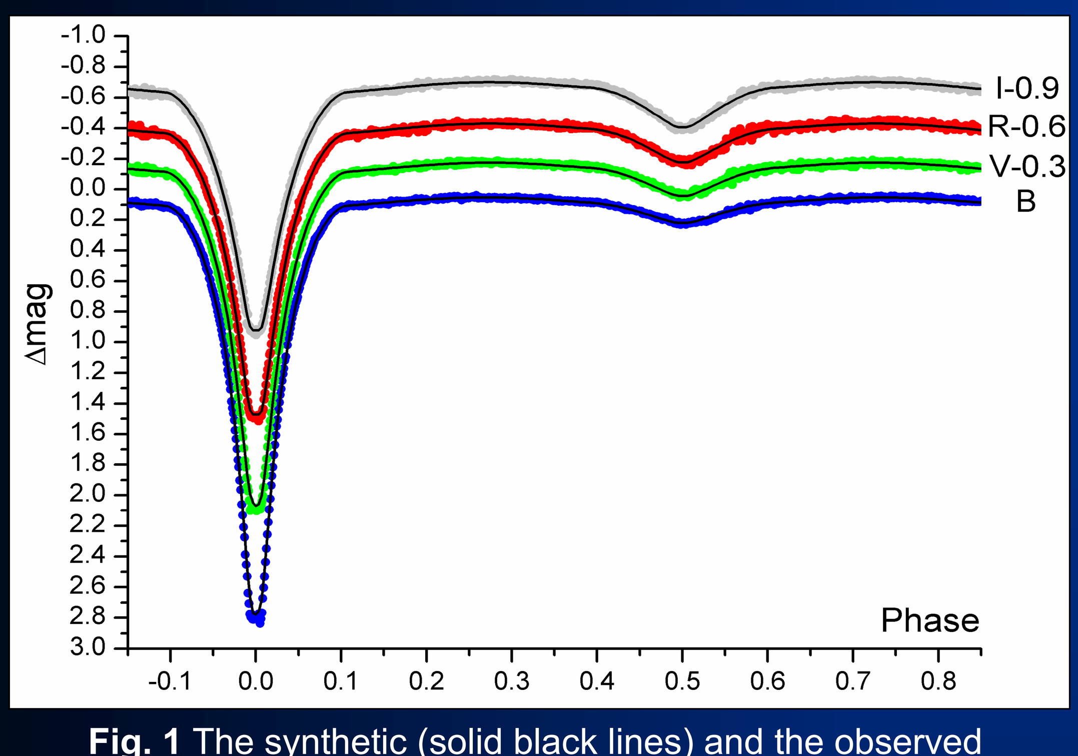

Fig. 1 The synthetic (solid black lines) and the observed light curves (colored points) of X Tri in B, V, R, I filters.

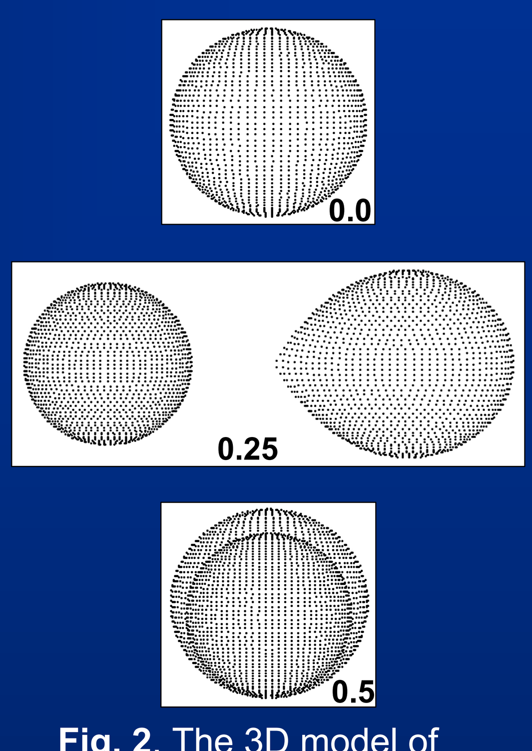

Fig. 2. The 3D model of X Tri in various phases.

Table 1. The parameters of X Tri derived from the light curve solutions

Parameter	Value	Parameter	Value			
q	0.599 (2)		B	V	R	I
i (deg)	87.9 (1)	x_1**	0.551	0.478	0.402	0.322
T_1 (K)*	8600	x_2**	0.835	0.692	0.597	0.503
T_2 (K)	5188 (4)	L_1/L_T	0.893 (2)	0.839 (2)	0.795 (2)	0.739 (1)
A_1*- A_2*	1 - 0.5	L_2/L_T	0.107 (1)	0.160 (2)	0.201 (2)	0.246 (3)
g_1*- g_2*	1 - 0.32	L_3/L_T	0.000 (1)	0.000 (1)	0.004 (1)	0.015 (2)
Ω_1	4.27 (1)		Pole	Point	Side	Back
Ω_2	3.06	r_1	0.270	0.281	0.274	0.279
χ^2	1.278	r_2	0.314	0.448	0.328	0.361

*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 X Tri includes 571 times of minima taken from the literature and one time of minima from our observations (see Table 1). The following ephemeris *Min.I = HJD 2422722.285 + 0.9715341^d × E* (Kreiner et al. 2001) was used to compute, initially, the O-C points of all compiled times of minima.

Due to the multi-periodic distribution of the O-C points, three periodic LITE curves and one parabola were chosen to fit the O-C diagram. The final fit, the residuals of the analysis and the individual solution for each LITE are presented in Fig. 3, while the derived parameters are given in Table 2.

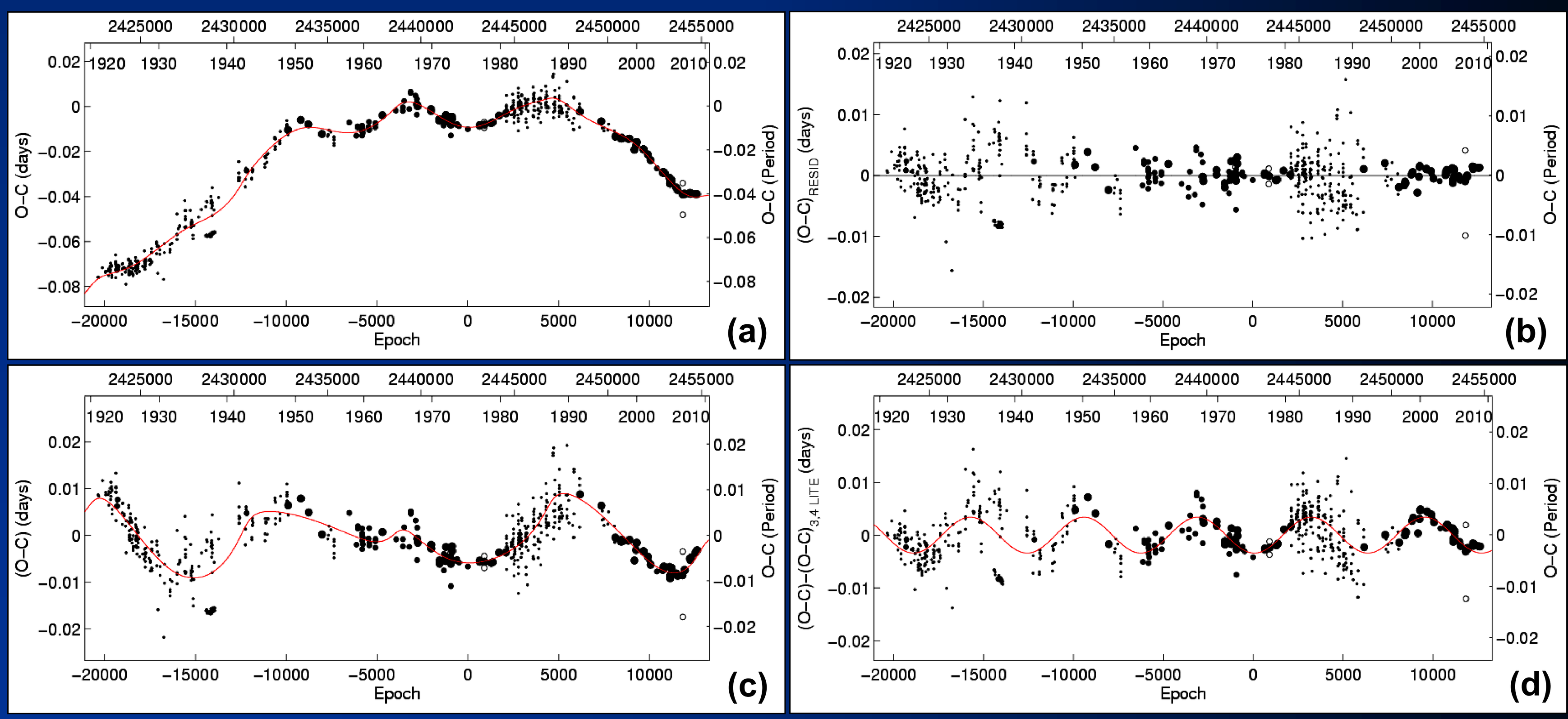

Fig. 3 (a) The O-C diagram of X Tri fitted by three periodic curves and a parabola which consist the total solution (solid line). (b) The O-C residuals after the subtraction of the total solution. (c) The O-C residuals after the subtraction of the parabola and the first periodic term, fitted by the second and third periodic curves. (d) The O-C residuals fitted by the third periodic term, after the subtraction of the first two periodic curves and the parabola. 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 2. The results of the O-C analysis for X Tri

Parameters of the EB			
M_1* + M_2 ($M_\odot$)	2.1 + 1.26		
Min. I (HJD)	2442502.731 (2)		
P (days)	0.9715318 (2)		
c_2 (days/cycle) (×10^{-10})	-2.0308 (2)		
$\dot{P}$ (days/yr) (×10^{-7})	-1.5269 (2)		
$\dot{M}$ ($M_\odot$/yr) (×10^{-7})	-1.6503 (2)		
Parameters of the LITEs			
	3rd body	4th body	5th body
P (years)	36.9 (5)	22.4 (3)	16.8 (4)
T_0 (HJD) (periastron passage)	2452916 (373)	2455069 (335)	-
ω (deg) (periastron passage)	220 (98)	34 (13)	-
A (days) (semi-amplitude of O-C)	0.0052 (3)	0.0040 (4)	0.003 (2)
e	0.2 (2)	0.5 (1)	0.0
f (m) ($M_\odot$)	0.00055 (5)	0.00094 (2)	0.0007 (3)
M_{min} (for i´=90°) ($M_\odot$)	0.18 (1)	0.24 (1)	0.22 (1)
χ^2	0.01197		

*taken from literature

5. Discussion and Conclusions

Complete BVRI light curves were obtained for the eclipsing system X Tri. The results of the light curve solutions show that X Tri is a semi-detached system with the secondary star filling its Roche Lobe. Although the obtained light curve solutions fit the observations very well, a spectroscopic mass ratio is needed to check the photometric one found in the present analysis. The periodic variations of the orbital period of the system could be explained by adopting the existence of additional components, which found to have minimal masses 0.18, 0.24 and 0.22, respectively. Moreover, the third periodic term was found to have a zero eccentricity, indicating a sinusoidal variation, but it is also possible to be caused by another physical mechanism, such as magnetic activity, although its signature (O'Connell effect) was not observed. An additional light contribution to the luminosity of the EB was taken into account in the light curve solution but it was found less than 1%. Such an extra luminosity could be explained by the small values minimal masses of possible additional components found. Their contribution to the total luminosity is almost negligible, but they affect the orbital period of the EB. The steady decrease rate of its period is probably due to angular momentum loss, since the direction of the flow (from the more massive to the less massive component), revealed from the O-C diagram analysis, comes in disagreement with the one derived from the light curve analysis.

6. Acknowledgements

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