The Light-Time Effect in the Eclipsing Binaries GK Cep and VY Cet

A. Liakos and P. Niarchos

Department of Astrophysics, Astronomy and Mechanics, Faculty of Physics, National and Kapodistrian University of Athens, Athens, Greece

Abstract

New times of minima of the eclipsing binaries GK Cep and VY Cet, obtained at the Athens University Observatory, have been used together with all reliable timings found in the literature in order to study the period variation and search for the presence of third body in the systems. The apparent period changes and the mass transfer between the two components of the eclipsing pair are studied through their O-C diagrams and with respect to the possible Light-Time Effect (LITE). New improved ephemerides for the eclipsing binaries, and orbital and physical parameters of potential third bodies are given.

1. Introduction

GK Cep (BV 382 = BD 70°1183 = HD 205372 = SAO 10069) is a long period (~0.93 days) W UMa system. The system was studied photometrically by Ruiz & Stokes (see Gleim 1967), Gleim (1967), Bartolini *et al.* (1965), Hutchings & Hill (1973), Dworak (1975) and Rovithis- Livaniou *et al.* (1990). A spectroscopic study of the system was carried out by Bartolini *et al.* (1965), and a period study was presented by Derman & Demircan (1992). These studies revealed that the system is a partially eclipsing system of W UMa-type with very similar massive components of early spectral type (A2V + A2V). B and V photoelectric observations were obtained by Erdem (2001) whose new period study confirmed the LITE in the system. Its period is one of the longest periods known for W UMa-type systems. The light curves show asymmetries probably due to mass transfer in the system, while its period is not constant, indicating the presence of a possible third body in the system. VY Cet (AN 158.1932 = BD -20°345 = CSV 168) was discovered to be an eclipsing binary by Hoffmeister (1933) who observed the system photographically. The first photoelectric light curves in UBV were obtained by Lapasset & Claria (1986) who derived a linear ephemeris of the system. According to their photometric solutions, VY Cet was classified as a W-type overcontact binary. Maceroni & van't Veer (1996) derived absolute parameters of the system. Qian (2001) presented a period study and suggested the presence of a third body in the system in order to explain the periodic oscillation of the system's orbital period.

2. Observations

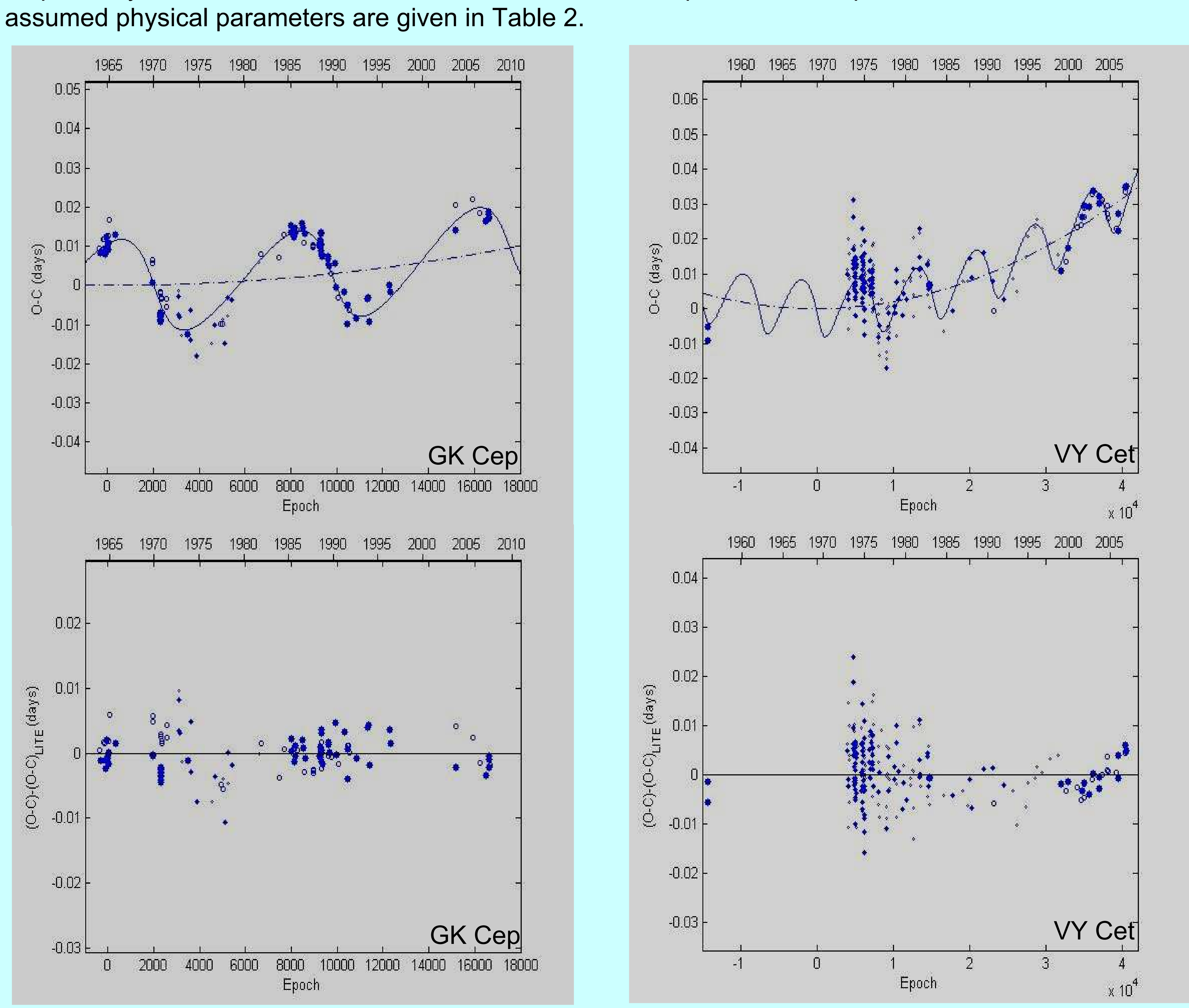
Both systems were observed with the 40-cm Cassegrain telescope of the Observatory of the University of Athens, equipped with the ST8XMEI CCD camera and Bessell VRI filters. For GK Cep the observations were carried out during one night in January 2007 and two nights in June 2007, and for VY Cet during one night in December 2006 and one night in January 2007. Differential magnitudes were obtained for both systems. For GK Cep the stars SAO 10066 and GSC 4465:0372, and for VY Cet the stars GSC 5857:1891 and GSC 5857:1297 were used as comparison and check stars, respectively. Two primary and one secondary minima for GK Cep, and one primary and one secondary minima for VY Cet were obtained and they are given in the Table 1.

Table 1. The times of minima from our observations

GK Cep			VY Cet		
HJD (2400000+)	Error	Type	HJD (2400000+)	Error	Type
54114.27388	0.00002	I	54090.23533	0.00019	II
54273.42250	0.00010	I	54102.33443	0.00008	I
54279.50782	0.00013	II			

3. Analysis of the O-C diagrams

We used only reliable times of minima, 120 for GK Cep and 231 for VY Cet, taken from the literature, and the new minimum times from our observations listed in Table 1. The O-C residuals of all compiled times of minima have been computed, initially, according to the linear ephemeris T = 2438694.7015 + 0.93616376 × E (Kreiner et al. 2001) for GK Cep, and T = 2440282.15273 + 0.340809368 × E for VY Cet (modified ephemeris from Kreiner et al. 2001). The O-C diagrams have been analyzed with the least-squares method and the results are presented in the Figures 1-4. Figures 1 and 2 show the O-C diagrams fitted by a parabolic and sinusoidal curve, thus suggesting a mass transfer between the components and the presence of a third body in the systems. In Figures 3 and 4 the residuals, obtained by subtracted both LITE and mass transfer solutions, are presented for GK Cep and VY Cet, respectively. The new elements for the binaries, the orbital parameters of possible third bodies and their assumed physical parameters are given in Table 2.



Figs. 1 - 4. The O-C diagrams of GK Cep (upper left) and VY Cet (upper right) fitted by a parabolic and a sinusoidal curve and the residuals obtained by subtracting both LITE and mass transfer solutions (lower left for GK Cep and lower right for VY Cet). The bigger the symbol the bigger the statistical weight. The circles represent CCD and photoelectric data, while the diamonds correspond to visual and photographic minima times. The filled and unfilled symbols are used for the primary and secondary minima times, respectively.

Table 2. The new parameters of GK Cep and VY Cet and the orbital and physical parameters of the third body in each system

Parameter	GK Cep	VY Cet
The physical and orbital parameters of the eclipsing binary		
$M_1 + M_2$ ($M_\odot$)	2.7 + 2.5	1.02 + 0.68
Spectral type	A2V + A2V	G5
q (days/cycle) (×10^{-10})	0.30960 ± 0.00004	0.19720 ± 0.00001
$\dot{P}$ (days/yr) (×10^{-8})	2.4158 ± 0.0003	4.2267 ± 0.00002
$\dot{M}$ ($M_\odot$/yr) (×10^{-7})	2.9031 ± 0.0003	8.4333 ± 0.0004
A (semi-amplitude of O-C) (days)	0.0117 ± 0.0004	0.0082 ± 0.0005
x^2 (sum of square of residuals)	0.0063854894766	0.0103336605213
The orbital parameters of the third body		
e_3	0.45 ± 0.06	0.39 ± 0.13
T (periastron passage) (HJD)	2455140.816 ± 155.377	2430113.271 ± 186.074
ω_3 (deg)	181.4 ± 6.5	219.0 ± 18.5
$f(m_3)$ ($M_\odot$)	0.02994 ± 0.00001	0.0649 ± 0.00001
P_3 (yrs)	19.91 ± 0.19	7.07 ± 0.06
The physical parameters of the third body		
$m_{3,min}$ ($M_\odot$) (i = 90°)	1.0641 ± 0.0003	0.7250 ± 0.0009
Spectral type*	G0V	K3V
T_3 (°K)*	5940	4686
L_3 ($L_\odot$)*	1.35	0.26
R_3 ($R_\odot$)*	1.1	0.77
M_3 (mag)*	4.4	6.7

*assumed (theoretical values)

4. Discussion and Conclusions

New orbital and physical parameters for the eclipsing binaries GK Cep and VY Cet have been derived by means of an analysis of their O-C diagrams. A third body in an eccentric orbit with a period of ~20 years and a minimum mass of 1 $M_\odot$ was found for the case of GK Cep, while for the case of VY Cet, a third body in an eccentric orbit with a period of ~7 years and a minimum mass of 0.7 $M_\odot$ was also found. With the assumption that each of the third bodies is a main sequence star, their physical parameters were calculated and their luminosities ($L_3 \sim M_3^{3.5}$) were compared with the total luminosities ($L_1+L_2+L_3$) of the systems, respectively. For the case of GK Cep, a 2.1% contribution in total light was found from the third body, which is too small to be detectable, while the large contribution of 19.6% in total light from the third component in VY Cet, leads to the conclusion that its existence can be proved either spectroscopically or through a new modeling of the system. However, the cyclic changes in the O-C diagram of VY Cet could be also caused by magnetic phenomena. The O-C residuals of GK Cep show that an additional variation might exist, but its confirmation requires more times of minima in the next years. Assigning a weight of 1 to visual data, 5 to photographic data, and 10 to photoelectric and CCD observations, we found: a quadratic ephemeris T = 2438694.69719(159) + 0.9361642(2) × E + 0.30960(4) × 10^{-10} × E^2 and a period increase rate of dP/dt = 2.4158(3) × 10^{-8} days/yr for GK Cep; and T = 2440282.14835(132) + 0.3408091(1) × E + 0.19720(1) × 10^{-10} × E^2 and a period increase rate of dP/dt = 4.2267(2) × 10^{-8} days/yr for VY Cet. For both cases the parabolic term indicates a mass transfer from the less massive to the more massive component of the system.

5. Acknowledgements

We thank P. Zasche for providing the Matlab code to compute the LITE elements. This work has been financially supported by the Greek-Czech project of collaboration GSRT 214-γ of the Ministry of Development (Special Account for Research Grants 70/3/8680 of the National & Kapodistrian University of Athens, Greece).

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MEARIM, Cairo, Egypt, April 5-10, 2008