The contact system DF Hya revisited

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Abstract

New BVRI CCD photometric observations of the contact system DF Hya have been obtained. The light curves were analyzed with the Wilson-Devinney code and new geometric and photometric elements were derived. Moreover, the light curve solution, with the assumption of a third light in the system, revealed the existence of a tertiary component around the eclipsing pair. The present results are compared with those of other recent studies.

1. Introduction

DF Hya is a contact system of W UMa-type with a period of 0.3306022^d. Its variability was discovered by Hoffmeister (1934). Srivastava (1991) proposed abrupt period changes, while Zhang et al. (1989) suggested mass transfer between the components. Liu et al. (1990) conducted photometric observations of the system and a photometric solution was given suggesting an unevolved contact binary. Niarchos et al. (1992) based on their own observations published the system's basic physical properties and derived two possible mass ratio values. Zasche et al. (2009) performed orbital period analysis and proposed the existence of a third body with a minimal mass of 0.84 $M_\odot$. Xiang et al. (2009) identified a 21.5 yr orbital period modulation and suggested a tertiary companion with a minimal mass of 0.21 $M_\odot$ around the binary and mass transfer from the secondary to the primary component as the most possible solution. The spectral type of the system is G0V according to Malkov et al. (2006).
The CCD light curves presented here were analysed with the aim to obtain a new photometric model of the system with better accuracy than previous studies, calculate its absolute elements and search for tertiary component around it.

2. Observations and data reduction

The system was observed during the night of January 17 2011 at the Gerostathopoulion Observatory in Athens University using a 40-cm Cassegrain telescope equipped with the CCD camera ST-10XME and B, V, R and I Bessell photometric filters. Differential magnitudes were obtained with the software *MUNIWIN v.1.1.26* (Hroch 1998), while GSC 0225-0943 and GSC 0225-0731 were used as comparison and check stars, respectively.

3. Light curve analysis and absolute parameters calculation

The light curves were analysed with the *PHOEBE v.0.29d* software (Prša & Zwitter 2005). Mode 3 (contact system) was chosen for fitting applications and the 'q search method' was applied for an estimation of the mass ratio with a step of 0.1 in the range of 0.1-10. A graph displaying the q search values is displayed in Fig. 3. This value then was adjusted in the subsequent analysis. The temperature of the primary component was set as a fixed parameter (T_1=6000 K), while the temperature of the secondary was left free. The albedos A_1, A_2 and gravity darkening coefficients g_1, g_2 were given theoretical values according to the component's spectral types. The potentials Ω_1, Ω_2, the system's inclination i and the fractional luminosity of the primary component L_1 were also adjusted. The limb darkening coefficients x_1, x_2 were taken from the tables of Van Hamme (1993). Given the evidence for third body existence in the system (Zasche et al. 2009; Xiang et al. 2009) the third light parameter l_3 was trialed. Synthetic and observed light curves and the 3D model of the system are shown in Figs 1 and 2, respectively, with corresponding parameters given in Table 1.
The absolute parameters of the components were calculated (Table 1) and used for further study of their present evolutionary status. Two cases are considered: **(A)** The mass of the primary (hotter) and **(B)** the mass of the secondary (cooler) assigned values according to their spectral types as Main Sequence stars. The location of the components in a theoretical Mass-Radius diagram is illustrated in Fig. 4 for both cases.

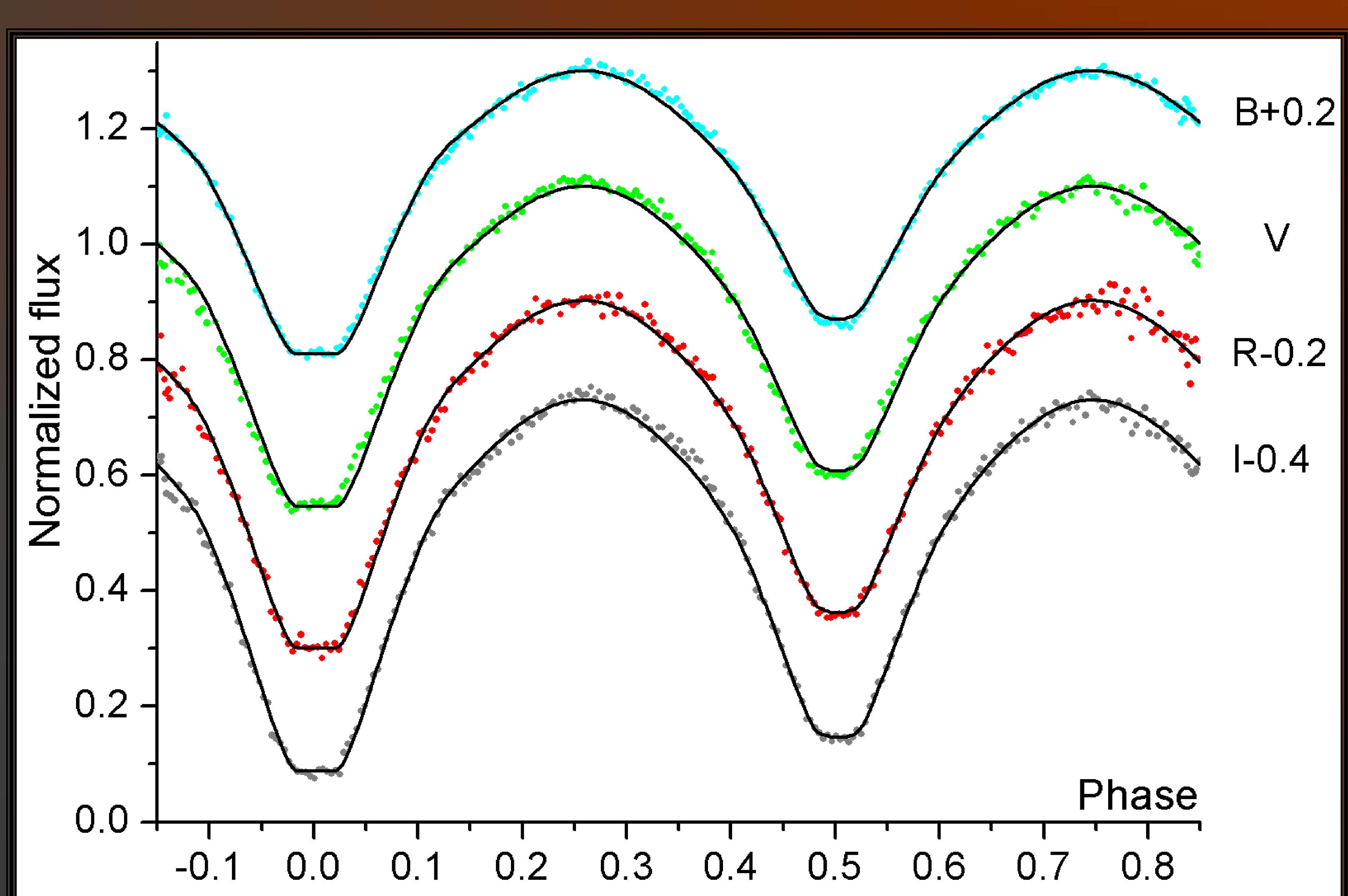

Fig. 1. Observed (coloured points) and synthetic (solid lines) light curves of DF Hya.

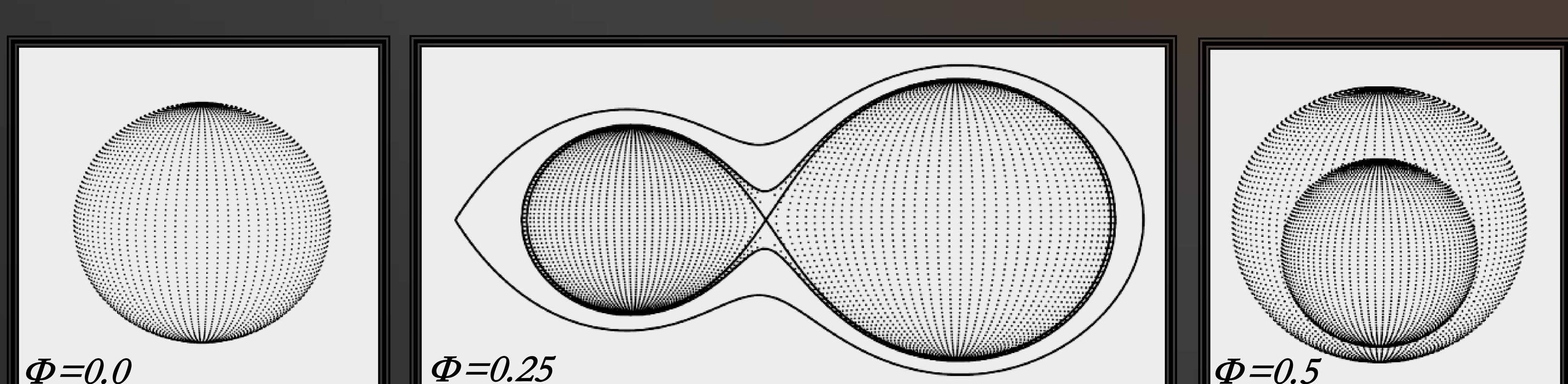

Fig. 2. Simulated view of DF Hya in various phases.

Table 1. Light curve solution and absolute parameters of the components of DF Hya

Parameter	Value			
	System parameters			
q	2.38 (1)			
i [deg]	84.8 (2)			
Component:	*P*		*S*	
g	0.32*		0.32*	
A	0.5*		0.5*	
T [K]	6000*		5620 (5)	
Ω	5.68 (1)		5.68 (1)	
Filter :	*B*	*V*	*R*	*I*
L_1/L_T	0.445 (5)	0.373 (4)	0.365 (2)	0.357 (1)
L_2/L_T	0.509 (2)	0.604 (2)	0.617 (1)	0.628 (1)
L_3/L_T	0.046 (8)	0.023 (7)	0.017 (3)	0.015 (3)
x_1	0.709	0.572	0.490	0.411
x_2	0.764	0.623	0.537	0.452
	Absolute parameters			
	Case A		**Case B**	
Component:	*P*	*S*	*P*	*S*
M [$M_\odot$]	1.07*	2.5 (2)	0.39 (3)	0.94*
R [$R_\odot$]	0.97 (2)	1.44 (2)	0.70 (2)	1.03 (2)
L [$L_\odot$]	1.10 (5)	2.41 (6)	0.56 (3)	1.23 (3)
M_{bol} [mag]	4.64 (2)	4.08 (2)	5.37 (2)	4.81 (2)
a [$R_\odot$]	2.17 (6)	0.91 (3)	1.56 (5)	0.66 (2)
log g [cm/s^2]	4.49 (2)	4.53 (5)	4.34 (4)	4.39 (1)

*assumed, P=primary, S=secondary, $L_T=L_1+L_2+L_3$

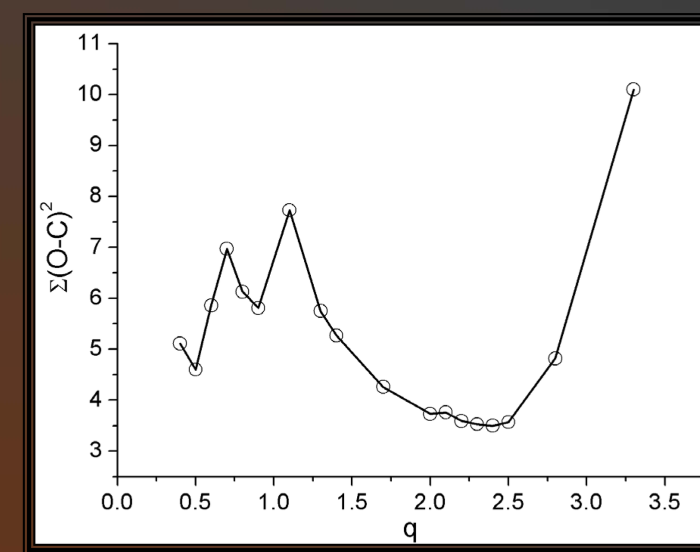

Fig. 3. Diagram displaying the fitting residuals for a range of q values.

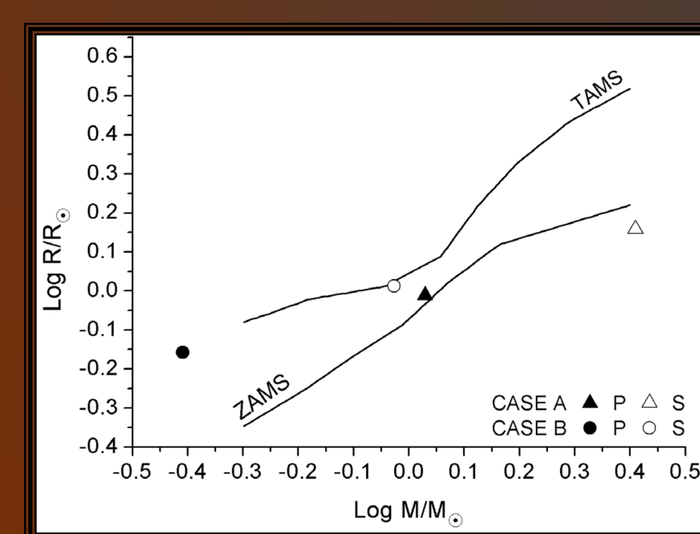

Fig. 4. The location of the components of DF Hya in the M-R diagram for both cases. Black solid lines indicate the Terminal Age Main Sequence (TAMS) and Zero Age Main Sequence (ZAMS) limits.

4. Discussion and conclusions

New photometric study of the eclipsing binary DF Hya was performed and new geometric elements of the system and absolute parameters of its components were derived. The system is of W-type, meaning that the primary component (hotter) is less massive and smaller than the secondary. The components' location in the M-R diagram (see Fig. 4) for Case A indicate that the secondary is a pre-Main Sequence star with a mass of 2.5 $M_\odot$, which is quite unusual for members of W UMa systems. The second hypothesis (Case B) seems to be more likely as both stars lie inside the ZAMS-TAMS limits and therefore it is suggested as the most realistic one.
The comparison between the present light curves and the ones given by Niarchos et al. (1992) shows that brightness changes occur in the system affecting both the minima and maxima. In order to check any brightness variation periodicities, long term monitoring of the system is required.
For an accurate solution a third light was considered in the light curve analysis and a contribution of ~2.5% was found. According to the O-C analysis results of Zasche et al. (2009) ($M_{3,min}$=0.84 $M_\odot$), and assuming the MS nature of the tertiary component and taking into account the Mass-Luminosity relation for MS stars ($L \sim M^{3.5}$), the expected light contribution was found ~25%, which is much larger than the observed one. A possible explanation for this mismatch could be a binary star orbiting DF Hya instead of a single one. On the other hand, the orbital period analysis of Xiang et al. (2009) suggested a minimal mass of 0.21 $M_\odot$ for the additional component and mass transfer between the binary's members. This value does not satisfy also the observed light contribution, but if we assume a non coplanar orbit of the third body with an inclination of ~30°, then the result can be adopted. The Applegate mechanism was also tested for Zasche et al. (2009) results, but it was found that the quadrupole moment variation for both stars ($\Delta Q < 10^{50}$ gr cm^2) cannot implicate the period changes (cf. Lanza & Rodonò 2002). Hence, the third body existence remains as the most possible solution for the orbital period modulations of the system.
Spectroscopic observations are needed in order to check the value of the present photometric mass ratio and provide the information for a more accurate determination of the absolute parameters.

5. Acknowledgements

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